AMENDED

Broad Agency Announcement (BAA)

Ubiquitous High Performance Computing (UHPC)

Transformational Convergence Technology Office (TCTO)

DARPA-BAA-10-37

March 9, 2010

Table of Contents

Part One: Overview Information

- **Federal Agency Name –** Defense Advanced Research Projects Agency (DARPA), Transformational Convergence Technology Office (TCTO**)**
- **Funding Opportunity Title –** Ubiquitous High Performance Computing (UHPC)
- **Announcement Type –** Initial Broad Agency Announcement (BAA)
- **Funding Opportunity Number –** DARPA-BAA-10-37
- **Catalog of Federal Domestic Assistance Numbers (CFDA) –** N/A
- **Key Dates**
  - Posting Date – see announcement at www.fbo.gov
  - Proposal Due Date
    - Initial Closing – 1200 noon (ET), 16 April 2010
    - Final Closing – 1200 noon (ET), 30 August 2010
- **Anticipated Awards –** Multiple awards are anticipated for Technical Area 1 (TA1) and a single award for Technical Area 2 (TA2).
- **Types of Instruments That May Be Awarded –** Procurement contract or other transaction.
- **Technical POC –** Dr. William Harrod, Program Manager, DARPA/TCTO
  - EMAIL: DARPA-BAA-10-37@darpa.mil
  - FAX: (703) 465-8096
  - ATTN: DARPA-BAA-10-37
    3701 North Fairfax Drive
    Arlington, VA 22203-1714

Part Two: Full Text of Announcement

I. *FUNDING OPPORTUNITY DESCRIPTION*

The Defense Advanced Research Projects Agency (DARPA) often selects its research efforts through the Broad Agency Announcement (BAA) process. This BAA is being issued, and any resultant selection for negotiation and/or award will be made, using procedures under FAR Part 35.016. Proposals received as a result of this BAA shall be evaluated in accordance with evaluation criteria specified herein through a scientific review process. The BAA will appear on the Federal Business Opportunities website, http://www.fedbizopps.gov/. The following information is for those wishing to respond to the BAA.

DARPA is soliciting innovative research proposals in the area of computer system research and development. Proposed research should investigate innovative approaches that enable revolutionary advances in science, devices, or systems. Specifically excluded is research that primarily results in evolutionary improvements to the existing state of practice.

Introduction

As the world moves towards a "paperless" society, computing systems are becoming the essential backbone of both DoD and civilian activities. All current DoD sensors, platforms, and missions heavily depend on computer systems – from in-field distributed sensors to complex weapons system simulations. Current evolutionary approaches to progress in computer designs are inadequate. To meet the relentlessly increasing demands for greater performance and higher energy efficiency, revolutionary new computer systems designs will be essential to support new generations of advanced DoD system capabilities and enable new classes of computer applications. To achieve these capabilities, DARPA is releasing a Broad Agency Announcement (BAA) for the Ubiquitous High Performance Computing (UHPC) program. Novel proposals for complete systems are sought. Individual technologies or partial solutions will not be considered.

There are three extremely significant problems for future computer systems: power consumption, cyber resiliency[1], and user productivity[2].

In 2007, the EPA[3] reported the following to Congress:

> Under current efficiency trends, national energy consumption by servers and data centers could nearly double again in another five years (i.e., by 2011) to more than 100 billion kWh, representing $7.4 billion annual electricity cost. The peak load on the power grid from these servers and data centers is currently estimated to be approximately 7 gigawatts (GW),

[1] "Cyber Resilience for Mission Assurance", Unrestricted Warfare Symposium (URW), March 2009,
[2] "Special Issue on HPC Productivity", The International Journal of High Performance Computing Applications, Volume 18, Number 4, Winter 2004
[3] "Report to Congress on Server and Data Center Energy Efficiency", U.S. Environmental Protection Agency, August 2, 2007

> equivalent to the output of about 15 baseload power plants. If current trends continue, this demand would rise to 12 GW by 2011, which would require an additional 10 power plants.

The estimated cost of a new power plant is $1.5B[4]. It is imperative that future computers utilize considerably less power.

Cyber resiliency, the ability to operate a computing network or system through attack and failure, is critical to mission performance. Over 140 countries around the world have cyber weapon developments underway. Of all worldwide reported attacks, more than 85% are against the United States[5]. NATO now considers Cyber defense at the level of missile defense and energy security, and intrusion attacks are increasing dramatically[6] (the number of attempted intrusions to federal agencies reported to US-CERT has increased by 206% from FY06 to FY08[7]). Cyber resiliency must be pursued in all levels of the proposed UHPC system design.

User productivity is the ability to effectively develop applications in as short a time as possible while delivering maximum computing system capabilities. It is commonly believed that for most deployed computer systems, the cost of developing the software is substantially greater than the cost of the hardware. Future computing systems will involve extreme scale concurrency and complexity. These systems will require “hero” programmers to develop high performance applications, which will drive the cost of software development substantially higher. Furthermore, if user productivity is not improved in conjunction with the hardware, the benefit of the hardware improvements will be lost to the consumers. The potential of future computing systems will be significantly limited unless this problem is resolved.

The UHPC program will develop the architectures and technologies that will provide the framework and underpinnings for the resolution of the power consumption, cyber resiliency, and productivity problems. The UHPC program will develop computer systems, from the embedded to cabinet system levels, that have extremely high-energy efficiency. These systems will have dramatically reduced power consumption while delivering a thousand fold increases in capabilities. The dependability technologies developed under the UHPC program will provide adaptable and hardened computer systems that will enable cyber resiliency. Productivity will be significantly improved by developing scalable, highly programmable computer systems that don’t require excessive system expertise for the development of high performance applications.

The UHPC vision will enable scalable, revolutionary architectures and technologies needed to meet the steadily increasing broad demands of DoD applications – from embedded to command center. The program will develop computers that have significantly improved power efficiency, ease of programming, and dependable execution through all modes of system attacks and

---

[4] “Vision and Roadmap:Routing Telecom and Data Centers Toward Efficient Energy Use”, May 13, 2009

[5] The Top Cyber Security Risks (http://www.sans.org/top-cyber-security-risks/)

[6] Defense Tech: Cyber-warfare Archives, There’s concern but Where’s the Action, pg 2 and Cyber Weapons and Ebombs, pg 80

[7] GAO Testimony Before the subcommittee on Government Management, Organization and procurement; House Committee on Oversight and Government Reform, Information Security-Cyber Threats and Vulnerabilities Place Federal Systems at Risk, GAO-09-661T, pg.7

failures. Technologies should be expandable to high performance, large scale computing systems; however such systems are not part of this solicitation. The UHPC Program does not state a maximum number of cabinets that should be supported.

To fully attain the vision and goals of the UHPC program and attack the driving problems stated above, the program must establish a open innovation environment. Open innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology[8]. An environment where researchers can openly exchange, debate and formulate revolutionary ideas concerning computer hardware, software and application technologies. These collaborations must occur within a project team, between project teams and are expected to involve researchers not funded by the UHPC program. These problems are of such a significant nature; one team cannot fully solve them!

Until recently, advances in Commercial Off-The-Shelf (COTS) systems performances were enabled by increases in clock speed, decreases in supply voltage, and growth in transistor count. These technology trends have reached a performance wall where increasing clock speed results in unacceptably large power increases, and decreasing voltage causes increasing susceptibility to transient and permanent errors. Only increasing transistor count continues to drive performance increases, with value only if energy can be minimized while optimizing the ability to efficiently utilize available concurrency. Further, increasing density has not helped reduce the energy costs of data transport across a chip, between neighboring chips, or between chips on disparate boards. Current interconnect protocols are beginning to require energy and power budgets that rival or dwarf the cost of doing computation.

Future processing systems must address a significant shift in the way computer systems manage dependability, including resiliency[9] and security. Today, the concept of dependable computer systems assumes perfect device fabrication and operation. Currently, attempts to provide highly dependable systems involve error correction codes (ECC) on memories and triple-modular-redundancy (TMR) of critical components. These brute force methods are able to increase system dependability at the expense of high overhead and increased associated system power.

Current systems are expected to deliver high individual device reliability and low variation. However, as the critical dimensions of devices, such as transistors and wires, used to implement computer systems shrink to nanometers and continued attempts are made to reduce operating voltages, rates of transient faults, permanent faults, and variation between devices on the same die will increase to the point where this approach will no longer be practical. To obtain the desired levels of performance chip and system variations must be actively managed. Current systems are not resilient; they do not intelligently utilize available system resources at all system levels (particularly chip level resources) to compensate for faults and failures. Industry has not included significant hardware support for security in commercially available architectures. Security traditionally has been addressed as an “add-on” via software layers and not integrated

[8] Chesbrough, H.W. (2003). Open Innovation: The new imperative for creating and profiting from technology. Boston: Harvard Business School Press, p. xxiv

[9] High-End Computing Resilience: Analysis of Issues Facing the HEC Community and Path-Forward for Research and Development, DARPA–BAA-10-37, URL: http://www.darpa.mil/tcto_solicitations.html

directly into the computing architecture. This has lead to inefficient and potentially ineffectual security solutions. Without new initiatives, industry's approach to security is not expected to change. Security must be implemented at all architectural levels and as a direct element of the execution model.

Processing systems have encountered a "memory wall" where memory performance is insufficient to provide the data required to fully utilize processing resources. This is a result of memory performance falling behind processing unit performance. Processor stalls result when processing units idle waiting for requested data. In addition, memory has become a significant source of energy consumption within computer systems. For these reasons, memory performance limits overall system performance.

To address these concerns the UHPC program will pursue, but will not be limited to:
1) development and optimization of ExtremeScale architectures, technologies, execution models, and the critical co-design of hardware and software; 2) low-energy architectures and protocols for logic, memory, data access, and data transport; 3) dynamic systems that adapt to achieve optimal application execution goals; 4) dependable[10] computer systems including resiliency and security at all system levels; 5) concurrency management and the efficient use of massively parallel resources; 6) locality-aware architectures to reduce data movement; 7) self-aware OS that manages real-time performance, dependability and system resources.

The UHPC program will develop solutions for radically new computer systems that overcome energy efficiency, dependability, and programmability challenges. The UHPC vision includes:

- **Efficiency:** New *system-wide* (hardware and software) technology approaches to minimize energy dissipation per operation and maximize energy efficiency, without sacrificing scalability to ultra-high performance DoD applications**.**
- **Programmability:** Develop new scalable system architectures and technologies that do not require application programmers to explicitly manage system complexity, in terms of architectural attributes with respect to data locality and concurrency, to achieve performance, time to solution and other goals**.**
- **Dependability:** Develop a system-wide approach to achieve dependability through fault management techniques enabling an application to execute correctly through both failures and attacks, and to protect the confidentiality and integrity of information, while achieving the user's goals. These goals could include performance, time to solution, energy efficiency or power consumption. Dependability across all levels of a UHPC System Design that is nearly transparent to the user and hardware performance**.**

To realize this vision requires reinventing how computers process and manage data and how applications are developed and executed. UHPC System Designs that merely pursue evolutionary development will not be considered.

[10] For a definition of dependability see the paper "Basic Concepts and Taxonomy of Dependable and Secure Computing" by Algirdas Avizzienis, Fellow, IEEE, Jean-Claude Laprie, Brian Randell , and Carl Landwehr, IEEE TRANSACTIONS ON DEPENDABLE AND SECURE COMPUTING, VOL. 1, NO. 1, JANUARY-MARCH 2004

The UHPC Program will pursue research and development efforts that will explore the technologies and architectures required to enable the development of revolutionary computing systems and overcome "business as usual" advances. Scaling current technology and justifying this approach with feature size reduction arguments cannot accomplish the goals of the program. This can only be achieved via dedicated investment, hardware-software co-design, integrated design techniques that utilize open innovation. Since creating an open innovation environment will be a critical element throughout the UHPC program and heavily weighted in all program evaluations, it should be an important consideration in team formation and plans for working with researchers outside of the proposed team. It must be noted that innovation for the sake of innovation will not be sufficient; proposers must demonstrate the viability, applicability and value to the overall UHPC System Design. Computers based on a UHPC System Designs will deliver extreme scale performance for modern DoD computational applications. It is assumed that system designs developed under this program will be scalable to systems ranging from embedded terascale systems up through at least single cabinet petascale configurations.

Terminology

The system components and definitions terminology are introduced as a convenience for the future descriptions found within this document.

General Definitions

Programmable System: Programmers are not required to explicitly manage the complexity of the system to achieve their performance, time to solution and other goals.

ExtremeScale System: A programmable system that is a thousand times more capable than a current comparable system, with the same power and physical footprint.

Execution Model: A paradigm for organizing and carrying out computation across all levels of the computer system. It provides the conceptual scaffolding for deriving system elements in the context of and consistent with all of the others. It is a coherent abstract schema that permits co-design and operation of such multiple layers.

UHPC System Design: A completely integrated highly programmable ExtremeScale system design that includes hardware and software co-design, execution model, self- aware operating system and prototype complier. UHPC Systems Designs will significantly advance energy efficiency, effective use of concurrency, and dependability for a broad spectrum of scalable applications, relative to the currently projected computer technology path.

UHPC System: A computer based on a UHPC System Design that achieves the UHPC vision and goals.

Non-UHPC Technology: Technology used within a UHPC System Design that is not funded by or developed under the UHPC program.

Dependability: System resiliency and security; resiliency includes maintainable, reliable, available, and correct; security includes confidentiality, correct, and available.

pJ: 1/(1,000,000,000,000) (pico) joules

GFLOPS: 1,000,000,000 (giga) floating point operations per second

TFLOPS: 1,000,000,000,000 (tera) floating point operations per second

PFLOPS: 1,000,000,000,000,000 (peta) floating point operations per second

B: 1 byte

GB: 1,000,000,000 (giga) bytes

TB: 1,000,000,000,000 (tera) bytes

System Components and Definitions

Module: The minimal, stand alone processing element including processing resources and memory

Node: A scalable implementation that includes multiple modules, interconnect network, and additional memory resources that are composed to create the cabinet in a UHPC System Design

Interconnection Network: A high performance fabric that connects modules and nodes

I/O System: Provides the high performance subsystem capable of streaming input or output data of various types

Storage System: Retains data for archival or scratch space

Program Background

The architectural advances that are required to build ExtremeScale computers (see Terminology section) have many significant hurdles to overcome. The technological advances that are required to build these systems was investigated and identified in the DARPA ExaScale (ExtremeScale) Study.[11] To achieve the goal of building these ExtremeScale computer systems the challenges of power, concurrency, memory/data density access and placement, and resiliency (dependability) must be concurrently addressed.

1. The Energy and Power Challenge is the most pervasive of the four identified challenges. A key observation is that it will be easier to solve the power problem associated with base computation than to reduce the problem of transporting data from one site to another - on the same chip, between closely coupled chips in a common package, between different

[11] ExaScale Computing Studies, DARPA–BAA-10-37, URL: http://www.darpa.mil/tcto_solicitations.html

racks on opposite sides of a large machine room, or on storing and accessing data in the aggregate memory hierarchy.

2. The Memory and Storage Challenge concerns the lack of currently available technology to retain data at high enough capacities (and access it at high enough rates) to support the desired application suites at the desired computational rate and still fit within an acceptable power envelope. This information storage challenge lies in both main memory (DRAM today) and in secondary storage (rotating disks today).

3. The Concurrency and Locality Challenge likewise grows out of the flattening of silicon clock rates and the end of increasing single thread performance, which has left explicit, largely programmer-visible, parallelism as the only mechanism in silicon to increase overall system performance. ExtremeScale systems may have to support upwards of a billion separate threads.

4. A Resiliency Challenge that deals with the ability of a system to continue operation in the presence of either faults or performance fluctuations. This concern grew out of not only the explosive growth in component count for the larger classes of systems, but also out of the need to use advanced technology, at lower voltage levels, where individual devices and circuits become more and more sensitive to local operating environments, and new classes of aging effects become significant.

These challenges cannot be pursued independently at the component level, such as processor, memory and network switches. They must be addressed as an integrated solution. Co-design of the system hardware and software that is driven by selected application domains processing requirements is essential. Solving individual challenges will not result in viable system solution. **The driving force behind these challenges is the need to minimize the metric, pJ/*op*, where "*op*" is any operation that must be performed to complete the execution of an application.** These are difficult challenges, but essential to enable the progress and advancement of future computer systems. Open innovation throughout the life of this program is critical for success.

One of the fundamental problems with current High Performance Computing (HPC) systems is that they are based on sequential models of computation that cannot efficiently utilize parallelism. A new model of computation or an execution model[12] must be developed that enables the programmer to perceive the system as a unified and naturally parallel computer system, not as a collection of microprocessors and an interconnection network. The execution model provides the conceptual scaffolding for deriving system elements in the context of and consistent with each other. Ideally, the execution model implements a decision chain where each layer contributes to the optimum determination of when, where, and how data placement, data movement, and operation of a computation are performed. Current execution models do not emphasize nor manage the specific characteristics critical to a system. This leads to inefficient use of system resources and premature saturation of system efficiency, as measured in terms of metrics such as GFLOPS per watt (GFLOPS/W).

[12] Execution Models, Thomas Sterling, LSU, URL: http://www.cct.lsu.edu/SSE/Exec_Models

An execution model has the following characteristics:

- Provides the governing principles for system design, operation, management, and application implementation;
- Impacts across all layers of the system design;
- Provides a conceptual framework for the co-design of all system layers;
- Supports the notion of the operation "decision chain," i.e.,
  - When, where, and why each operation is performed and
  - Every layer contributes to this decision process; and
- Permits reasoning and design decisions in addressing critical efficiency factors.

An execution model is *not*:

- A programming language, although it may strongly influence the underlying programming model semantics of which the language is a representation;
- A computer architecture, although it establishes the needs for low-level mechanisms that the architectures must support and provides the governing principles that guide the structures and actions of computer architecture in the performance of a computation; nor is it
- A virtual machine, which isolates the abstractions above from the implementation details below because it crosscuts all layers from programming language to architecture and influences all operation aspects of all system layers in concert.

A more detailed description of an execution model can be found in Appendix A, located on page 64 of this document.

ExtremeScale systems pose new critical challenges for system software in the areas of concurrency, energy efficiency and dependability. From an application viewpoint, the concurrency and energy efficiency challenges boil down to the ability to express and manage parallelism and locality by exploring a range of strong scaling and new-era weak scaling techniques. For expressing parallelism and locality, the key challenges are the ability to expose all of the intrinsic parallelism and locality in a programming model, while ensuring that this expression of parallelism and locality is portable across a range of systems. For managing parallelism and locality, the OS-related challenges include parallel scalability, spatial partitioning of OS and application functionality, direct hardware access for inter-processor communication, and asynchronous rather than interrupt-driven events, which are accompanied by runtime system challenges for scheduling, synchronization, memory management, communication, performance monitoring, and power management. To enable functionality and efficiency critical to future computing systems performance, system software stacks must be developed as an integrated capability that efficiently addresses functionalities across the system and between system layers. This is particularly true for energy efficiency and system dependability. These functions must be efficiently translated and implemented across all system layers to obtain overall system performance. Additional capabilities that the software stack must specifically support for future massively parallel computing systems is the ability to support and manage concurrent tasks and parallel resources and manage the contention caused by multiple clients requesting service from shared functionality and resources across the computing system. System software stack designs must move beyond today's statically layered implementations and move to approaches that coherently accomplish application objectives and implement functionality efficiently across the computing system.

A dependable system must incorporate multiple characteristics. These characteristics are shown below in Figure 1. Following are further discussions on security and resiliency as enabled by self-aware systems.

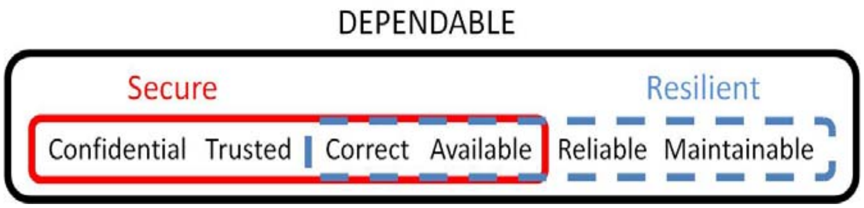

Figure 1 - Dependable System Elements

UHPC systems must be resilient to all classes of failures, both hardware and software components. Failures affecting a system's ability to accurately control its physical actions are of special concern, requiring a self-aware monitoring and reaction ability to enable high-performance nominal and safe post-failure operation. Approaches should consider techniques that unify formal software engineering with a suite of feedback control laws and efficient resource monitoring within a comprehensive design and development methodology.

Dependability includes the ability to trust data between functional elements and nodes to systems. For the UHPC system this includes the ability to trust data transferred between functional elements implemented as a single secure node through secure multi-node clusters within a cabinet. These techniques must be scalable at all levels, including the ability to scale to large-scale, multi-cabinet, potentially externally distributed trusted and non-trusted systems. Data security at all levels must implement "Trust, but verify."

The growing security threat for DoD and commercial, systems must be addressed. As stated in the recently released document, Cyberspace Policy Review:

> "Threats to cyberspace pose one of the most serious economic and national security challenges of the 21st Century for the United States and our allies. A growing array of state and non-state actors such as terrorists and international criminal groups are targeting U.S. citizens, commerce, critical infrastructure, and government."
>
> "Without major advances in the security of these systems or significant change in how they are constructed or operated it is doubtful that the United States can protect itself from the growing threat of cybercrimes and state sponsored intrusions and operations."

Current computer systems do not provide the necessary hardware and software support for securing the confidentiality and integrity of data and information processes. Systems are prone to leaking information. Information is vulnerable and can be exploited by security attacks. The UHPC program must develop the architectural and system level resources to prevent, detect, and respond to security threats. This will provide inherent security capabilities, but is not envisioned to defeat all current and future cyberspace threats.

To enable the desired security capabilities of the UHPC program, it is anticipated that the execution model, through a combination of hardware and/or software, will support at least 8 different privilege levels (for example, but not limited to, rings), with multiple protection domains (for example, but not limited to, virtual address spaces) per privilege level. There should be no preset limit to the number of protection domains per privilege level other than resource constraints. Protection domains should offer both memory protection and constrained control transfers into and out of the domain. In addition, to support computing system security, an execution model, again through a combination of hardware and/or software, should provide the property commonly known as "memory safety" for all programs, thereby preventing common security vulnerabilities such as buffer overflows, multiple de-allocations of the same memory region, return-to-libc attacks, etc. The execution model should support software running in one or more protection domains (in particular, software can be aggregated into a single domain for benchmarking purposes). Calls between protection domains should have sufficiently high performance to not limit their use. Given the highly concurrent nature expected of the UHPC program, it is desirable that security issues related to concurrency, such as race conditions and time-of-check-to-time-of-use (TOCTTOU) vulnerabilities, be addressed.

To realize the potential performance and dependability of a system for a specific application, all the system resources (both hardware and software) must be effectively utilized. Optimization and execution decisions should be made based both on the instantaneous system state and global knowledge of an application's behavior. Current operating systems have pre-programmed behaviors that are based on estimates of resource performance and availability. They are, therefore, ill suited to large-scale computers based on complex multicore processors and result in sub-optimal performance and potential system failure and attack in changing conditions.

Desirable Operating Systems (OS) and run-time solutions behave as a self-aware system[13] that "learns" to address problems by: building self-performance models; responding to user goals; adapting to changing goals, resources, models, and operating conditions; and maintaining confidentiality and integrity of information. Given the control of resources and multi-level management, the responsibilities of the OS and run-time may become blurred. The OS is expected to have the following characteristics:

- Introspective - it observes itself, reflects on its behavior, and learns;
- Goal-oriented - the system's client specifies the goal, and the system resolves how to accomplish the goal;
- Adaptive - the system analyzes the observations, computing the delta between the goal and observed state, and takes actions to optimize its behavior;
- Self-healing - the system continues to function through attacks and faults by taking corrective action; and
- Approximate - the system does not expend any more effort than necessary to meet goals

A notional Self-Aware OS (SAOS) is shown in Figure 2.

[13] Self Aware Organic Computing, DARPA–BAA-10-37, URL: http://www.darpa.mil/tcto_solicitations.html

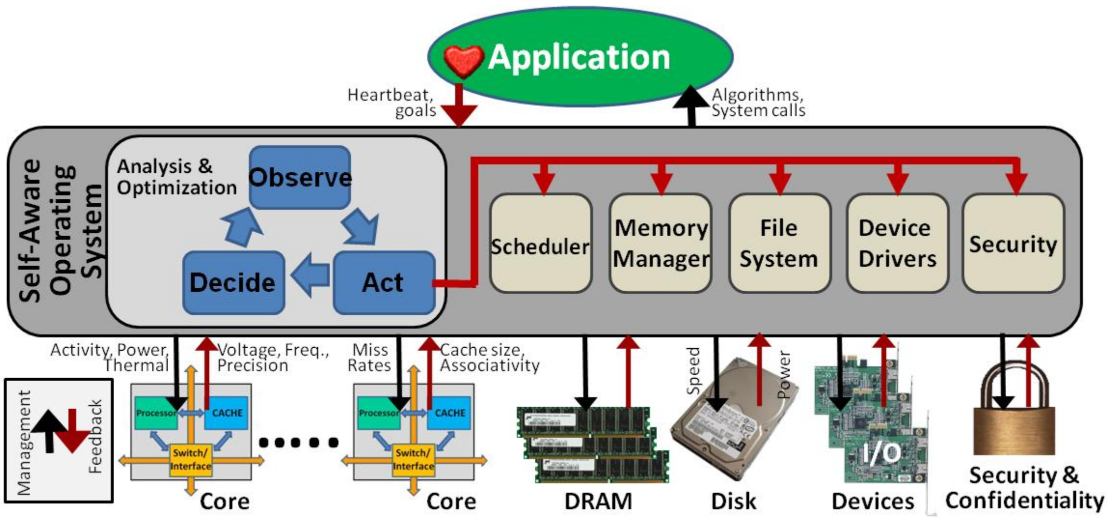

Figure 2 - Notional Self-Aware Operating System

A separation of concerns is achieved between the application and the SAOS. The application communicates goals and options to the SAOS. The SAOS uses observations and models of component performance to decide how best to meet application performance goals given system resources, actual observed performance, and dynamic system constraints.

In addition, computer system memory is a critical factor for delivering sustained high-level processor performance. Peak processor throughput capabilities are unattainable unless data is delivered to the correct destination when needed. As computing systems grow in complexity the ability to store, access, move, and position data has become and is increasingly a road block to high performance computing at all levels – from embedded applications to supercomputing.

There are significant memory challenges that limit the data availability necessary to support processing performance. First, memory performance is increasingly falling behind processor performance, resulting in the inefficient use of processor resources. Second, current and future applications require significantly greater memory capacities. Finally, increasing performance and capacity requirements on memory systems require memory solutions that reduce energy consumption. Current approaches involve evolutionary lower-power DRAM designs that are not able to achieve the requirements for more bandwidth and memory capacity. These challenges must all be addressed and overcome to fully realize compute system performance.

To reach the goals of the UHPC program, an integrated, hardware and software co-designed, multi-level, multi-discipline innovative and complete system approach is essential. Evolutionary advances, such as simply scaling current technologies justified by feature size reductions, or the combination of individual technology advances will be insufficient. UHPC System Designs do not need to be modeled or based on any existing design. The UHPC program must provide revolutionary approaches including energy, massive resource concurrency, dependability, data location and movement, self-aware capabilities, and the ability to program and effectively utilize system resources as one integrated system design.

To reach the energy goals alone will require reducing energy per operation from thousands of pJ/Op (representative of current processors), to tens of pJ/Op. As an example, achieving 50 GFLOPS/W is equivalent to expending only 20 pJ per floating point operation – a budget that must encompass far more than just the floating point operation: leakage losses, operand accesses, and operand transport, along with instruction issue and concurrency control. This will require energy-optimized solutions from the basic functional elements through subsystems and systems.

Approaches for the efficient use of massive parallel resources must be created, both for the programmer and for actual run-time application performance. This requires the system to be highly programmable by the application developer. The system software stack must have a global perspective of an application execution. In addition, the system itself must be cognizant of resource availability and performance and efficiently use resources at all system levels to optimize performance. Performance includes the ability to both optimally perform the application as well as to perform through failures, attacks and dynamic mission variations.

New approaches to the system execution model must be developed that recognize and utilize system resources and capabilities. The execution model and operating system developed must incorporate the ability to optimize the use of energy, concurrency, dependability (resiliency and security), and data locality to enable dependable and optimized performance of an application. Without the integrated solution of all of the above, the UHPC program cannot achieve its goals. By achieving the goals of the UHPC program, future, computationally demanding DoD missions will become achievable.

Program Description and Structure

The UHPC program will develop and prototype highly efficient, highly programmable and dependable ExtremeScale systems. The anticipated time frame for the availability of ExtremeScale systems is 2018. The transition targets for this program are DoD applications that depend on high-performance, power efficient, secure, and physically constrained computing resources. This program targets DoD computationally challenging problems that require systems capable of sustained performance approaching 10^{15} operations per second (peta*ops*) on real DoD applications that work with very large data sets and/or consume large amounts of memory.

There are five UHPC Challenge Problems (see below) that drive the development of a UHPC System Design. The UHPC Challenge Problems form a basis for all modern DoD application codes. Therefore, UHPC Systems will achieve high performance, high-energy efficiency, and high programmable and dependable for modern DoD Applications. The first challenge problem is a massive streaming sensor data problem resulting in actionable knowledge. The second challenge problem is a large dynamic graph-based informatics problem. The third is a decision class problem that encompasses search, hypothesis testing, and planning. The fourth and fifth challenge problems will be selected from DoD High Performance Computing Modernization Program (HPCMP) benchmark suite or the Computational Research and Engineering Acquisition Tools and Environments (CREATE) program. The UHPC application domain is defined to include all applications that are represented by the five UHPC Challenge Problems. Detailed specifications and models for the challenge problems will be provided after UHPC program initiation.

UHPC Goals

The goals of the UHPC program are as follows:

- Single cabinet system that achieves the UHPC program vision and goals. The hardware system goals areas described in Table 1 below.
- Self-aware OS and the resulting new system software stack.
- Prototype compiler for the new programming model, that enables ease of programming for an ExtremeScale system.
- Dynamic system that adapts to achieve optimal application execution goals, without the direct involvement of the application developer.
- UHPC System Design that supports modern high performance for scientific and engineering applications.
- UHPC System Design based on a multi-level model of dependability.
- Processor module that is capable of being used within terascale embedded and multiple cabinet systems.
- Development efforts must utilize open innovation and software and hardware co-design throughout the life of the program.

System Element	Goals
Cabinet	
Form Factor	Cabinet: width < 24 inches; height < 78 inches; and depth < 40 inches
Energy Efficiency	50 GFLOPS/W LINPACK (HPL)[14] benchmark
Peak Performance	1 PFLOPS (HPL)
Maximum Cabinet Power	57 kW including: UHPC System, storage system, fans, self contained cooling, high bandwidth I/O, etc.
Cooling	Self contained within cabinet. All approaches not requiring external resources are allowable.
Module	
I/O Capability	Support of massive streaming sensor data
Numeric Format – Floating Point	IEEE754 single and double precision, sufficient to support HPC compatible implementations of IEEE754
Numeric Format – Fixed Point	16, 32, and 64-bit supporting all arithmetic and logical/shift operations.
Memory and Bandwidth	Sufficient to support the UHPC application domain
System Memory	
Size and bandwidth	Sufficient to support the UHPC application domain
Interconnection Network	
Description	High performance computational environment supporting a shared global address space and overall system performance, and energy and concurrency efficiency. Support high performance interconnects at all levels of the system: inter-module, intra-module on a node, within a cabinet, and between cabinets.
External IO	
Description	Sufficient to support the UHPC application domain
Storage	
Description	Sufficient to support the UHPC Challenge Problems. This system could be comprised of non-volatile memory and/or disk drives. (Anticipated in the order of 10 B/FLOP)

Table 1 - Hardware Goals

The UHPC software effort spans operating systems; runtime systems for scheduling and lower level resource management; memory management; communication; performance monitoring; power management; self-aware operation; and prototype compilers. It is anticipated that a new system software stack will be developed for a UHPC System. The UHPC program will not provide funding for research and development of large-scale parallel file systems, high bandwidth I/O and storage technologies. However, it is a requirement that a UHPC System include these components.

[14] http://www.netlib.org/benchmark/hpl/

A significant problem is managing parallelism and locality. OS-related challenges include parallel scalability, spatial partitioning of OS and application functionality, direct hardware access for inter-processor communication, and fault isolation. There are additional challenges in runtime systems including scheduling, memory management, communication, performance monitoring, power management, and dependability. All of these must be solved by future ExtremeScale operating systems. The OS should be a self-aware system that "learns" to favorably respond to user goals and adapting to changing goals, resources, models, operating conditions, attacks and failures. Self-aware OS will take active measures to mitigate the effects of attacks and failures, closing exploited vulnerabilities.

A UHPC System must be highly programmable. The time required to develop a high performance application code by an application domain expert should not be substantially greater than the time required by a system specific expert programmer. The application developer should be able to implement parallel algorithms without having to develop sequential algorithms that are parallelized by using communication functions. The application development environment should allow an application developer to express all of the known parallelism and data locality characteristics for a particular application code and extract additional available parallelism. The expression of parallelism should be independent of the number of cores or other architectural elements of the system. The system should be scalable so that an executable can react to the loss of computational resources. The system itself must then be capable of selecting and configuring the appropriate computational elements. The system configuration must be capable of being dynamically modified during the execution of the code. A UHPC System must support these capabilities.

The UHPC development effort needs to emphasize revolutionary programming models that dramatically advance application development capabilities. A critical element of system dependability is how these system features will be exposed in the programming model. It is anticipated that an entirely new system software stack will be developed for a UHPC System. There is not an explicit requirement for the full development of a new programming language within the UHPC program. It is a requirement, however, that a prototype compiler be developed that demonstrates the ability of the UHPC System to achieve the program vision and goals. This prototype compiler will be used to demonstrate the UHPC program goals, including the metrics, benchmarks and application codes. UHPC Systems do not need to support legacy compilers, such as C and FORTRAN. The proposed programming model(s) must be suitable for scientific and engineering application software development, specifically the UHPC application domain.

The proposer must provide an initial "UHPC IP Lineage" document. This document must specify all IP that is utilized in a team's UHPC System Design, initially including all UHPC background IP and how it will be utilized. This document will be updated throughout the lifespan of the program as a Phase 1 and 2 deliverables. The document will provide a clear description of the IP, the ownership, licensees and rights associated with the IP.

The full development of an application development environment is not within the scope of the UHPC program. UHPC System hardware and operating system must enable the features specified in the previous paragraph. Demonstrating these capabilities is program requirement.

The proposed UHPC System Design must include a description of a programming model for the UHPC System.

To overcome the ExtremeScale challenges and to achieve the aggressive UHPC goals, a new execution model must be developed. Current execution models and system designs won't work at ExtremeScale because of their sequential execution foundations and inherent energy inefficiencies. The challenge of developing a new execution model that drives the development of a UHPC System Design and achieves the requirements is a significant research effort and a major component of the UHPC program. In addition, attempting to use current execution models at ExtremeScale will result in prohibitively large software development costs. Recent trends in High Productivity Computing Systems (HPCS) have demonstrated reductions in the human effort involved in developing high-productivity software for current petascale systems. This does not address the challenges of ExtremeScale architectures such as energy-efficiency, many-core parallelism and heterogeneous processors. It is anticipated that the results of the UHPC program will reinvent how computers operate and are utilized. This program does not promote any particular system architecture. Fundamentally, a system consists of processing and memory resources interconnected by a network fabric.

The final UHPC System Designs and supporting technologies developed under this program must have a demonstratable path to future products that could be used within a DoD mission scenario. **There is no requirement that a UHPC System Design be based on current economically viable technologies or that the resulting prototype UHPC System become a product.**

The proposal should specifically address additional areas and associated scaling to multiple-cabinet systems: cyber resiliency, inter-cabinet connections, implementation and management of file systems, and storage systems for large-scale system implementations. The UHPC program is developing designs that scale from embedded modules to the single cabinet level; however, the potential of designs to scale beyond a single cabinet should be considered at least at a conceptual design level. The enabling specifications, approaches, and potential designs to enable multi-cabinet implementations should be addressed and as a minimum conceptually presented as part of the proposed UHPC System Design. The proposed UHPC System Design, and UHPC Design documents, should specifically include the associated performance specifications and proposed conceptual design approaches for cyber resiliency, inter-cabinet connections, implementation and management of file systems, storage systems, and any other area that is deemed critical for future consideration of multi-cabinet system implementations. Multi-cabinet implementations are not an emphasis of the UHPC program, but will be a consideration regarding the potential overall value of the proposed UHPC System Design.

The above goals need to be achieved to enable the overall UHPC vision.

UHPC Challenge Problems

There are five UHPC Challenge Problems:

- Massive streaming sensor data problem resulting in actionable knowledge,

- Large dynamic graph-based informatics problem,
- Decision class problem that encompasses search, hypothesis testing, and planning,
- Two challenge problems drawn from DoD applications and to be selected after UHPC program initiation.

It is anticipated the UHPC Challenge Problems will be used to drive the development of UHPC System Designs. Large volumes of data of relatively low arithmetic intensity (math operations per data word) characterize massive streaming sensor data problems, with computations repetitively applied, and relatively small numbers of dynamic branches within the calculations. Typically, this flow consists of discrete blocks of data of a fixed volume, arriving at a fixed cadence. Representative sensor types include multichannel radar and electro-optic, infrared, and video imagers. Informatics problems rely on symbolic data rather than numeric or character-string data and are graph-based data structures rather than arrays (e.g., vectors, matrices). Typically data is composed of arrays of fixed rank and size represented by graph structures of symbolic elements accessed by relationship-based links and composed of symbolic or probabilistic associations. An informatics example is dynamic graph problems that include evolving massive informational structures and rapid morphing ephemeral structures. The former are typical of large ontological structures that to first order expand in response to continued incidence of new data or through inference. The latter are typical of planning and search trees such as found in optimization. A decision problem such as chess is a reasoning and command problem that relies on hypothesis testing, choice selection, and planning. A typical decision problem calculation involves a rapidly expanding tree data structure, searching a growing set of alternatives, and assessing their relative value or likelihood of achieving a desired outcome. The dynamics of calculation of decision problems is a rapidly altering tree structure (or more complicated directed graph) spread across a very large distributed system. An example is chess, which requires looking ahead to a partial degree, assessing the alternative paths that might ensue, and selecting the most promising one that will engender an ultimate win for the player. This is representative of command and control problems. The streaming sensor, dynamic graph, and decision problems are further described in Appendix B, located on page 66 of this BAA document.

The two remaining DoD application-based challenge problems could originate from the DoD High Performance Computing Modernization Program[15] (HPCMP) benchmark suite or the Computational Research and Engineering Acquisition Tools and Environments (CREATE) Program[16]. The HPCMP benchmark suite is anticipated to be composed of applications such as: AMR, GAMESS, HYCOM, LAMPS and a subset of the synthetic results (MultiMAPS and ICBENCH) for performance prediction for AUVS, CTH, and ICEPIC. The CREATE program design analysis tools are composed of: military aircraft, ship design, and RF antenna design and integration with platforms applications.

[15] High Performance Computing Modernization Program, URL: http://www.hpcmo.hpc.mil
[16] Software Applications Support: CREATE, URL: http://www.hpcmo.hpc.mil/cms2/index.php/aboutcreate

UHPC Program Metrics

The TA2 team will be responsible for determining primary and additional metrics that can be used to evaluate programmability, energy, dependability, and concurrency efficiencies of the proposed prototype systems. They will also generate metrics based on the five challenge problems. Each TA1 team will also generate a set of metrics that they will use to evaluate their proposed prototype system. Near the end of Phase 2, a more comprehensive set of metrics will be selected by DARPA. These metrics will be used to specify the goals of the system that will be built in Phase 3 of the UHPC program.

The initial primary metrics that will be used through the life of the program are:

- Energy efficiency: 50 GFLOPS/W for the HPL benchmark
- System Performance: 1 PFLOPS for the HPL benchmark
- Programmability: TBD
- Dependability: TBD
- Cabinet Power Requirement

The HPL benchmark is being used as a universally accepted benchmark that has been executed on many platforms, it is not intended to drive UHPC System Design, but as an existing available measurement tool relevant to computing system in general. During Phase 1, metrics will be selected and develop for programmability, energy efficiency, and dependability.

The five UHPC Challenge Problems will be used to drive UHPC System Designs and develop the appropriate system level metrics, not just evaluate performance. It is anticipated that additional primary metrics will be selected for Phases 2 and 4 of the UHPC program.

Program Scope

Figure 3 provides a summary of the system components that are considered to be within the funding scope for the UHPC program. Components within scope must be fully addressed in any viable UHPC proposal. Also shown are components that are partially within scope and not within scope for the UHPC program. Research and development areas not within scope may be addressed within UHPC activities, but will be expected to be funded by an alternate source, such as proposer R&D funding or developed using COTS technology.

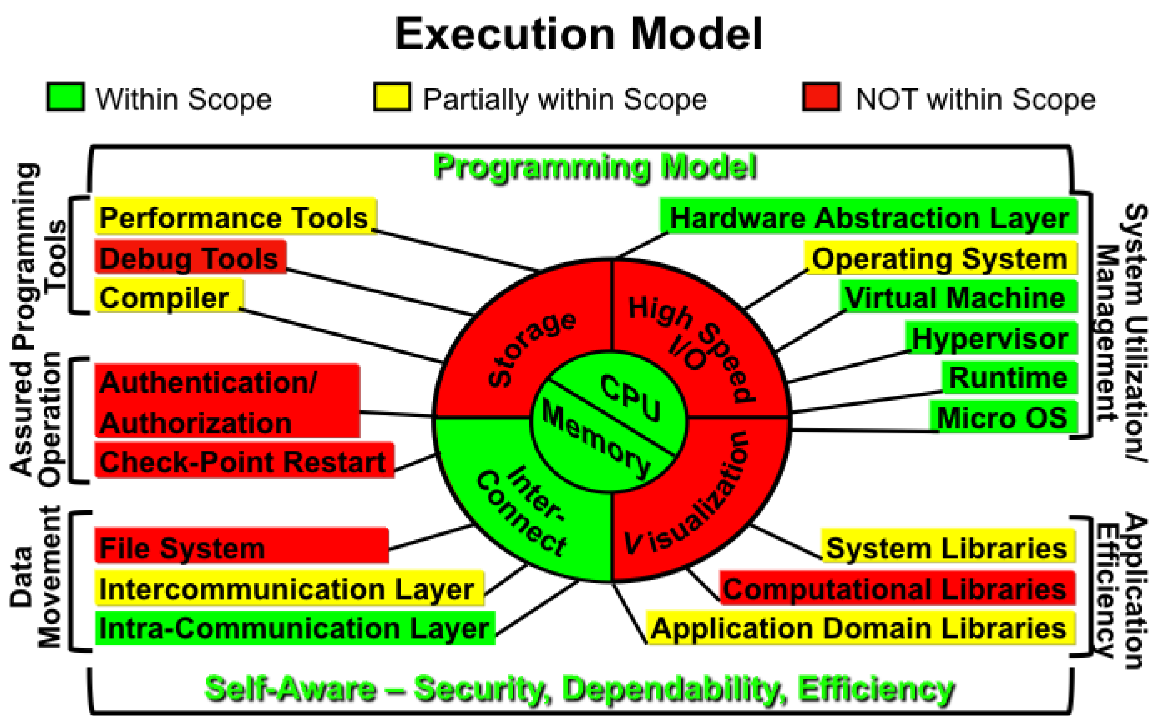

Figure 3 - UHPC Program Scope

It is expected that these components would be delivered in a current HPC system. There is no anticipation that a UHPC System Design will include all of the components shown in Figure 3, however, some aspect of the design will have similar functionality.

Program Structure

The UHPC program will have four phases. At the conclusion of Phase 2, subject to projected UHPC System characteristics, funding, and other program considerations, a solicitation may be issued to seek proposals for the third and fourth phases of work.

Phase 1, will focus on the initial execution models, conceptual UHPC System Design and an analytical analysis of the proposed system that will be used to show the performer's path forward, and provide initial metrics. Phase 2 will deliver the execution model, a preliminary UHPC System Design, preliminary hardware and software technologies demonstrations, a full system simulation, and evaluation using metrics that show progression toward achieving the program vision and goals, and the results of performance models for the UHPC Challenge Problems. Phase 3 will develop additional benchmark applications and complete the proposed design, build and delivery of an operational prototype UHPC System for test and evaluation. UHPC Systems must illustrate a capability to be modified to support in-field operations. Phase 4 will refine the prototype UHPC Systems within a laboratory environment, including completion of the prototype operating system and prototype compiler, and evaluate the prototype systems by executing the UHPC benchmarks and Challenge Problems.

A Technical Area 1 (TA1) team will be responsible for the research and development that is required to build a UHPC System that achieves the UHPC program vision and goals. The Technical Area 2 (TA2) team will be responsible for the development of the UHPC Challenge Problems, metrics, benchmarks and applications that will drive the development of a UHPC System Design and validate that the UHPC System can achieve the UHPC program vision and goals. DARPA anticipates multiple teams for Technical Area 1, but only one team for Technical Area 2. DARPA's decision to authorize Phase 2, as well as the number of teams for each phase, will be based on an overall assessment of Phase 1 performance. The Government reserves the right not to proceed with Phase 2 at its sole discretion, for example if no technically viable program exists or if funding is not available.

The two phases covered under this solicitation will have period of performances and funding splits as follows;

Phase 1 will be 24 months:

- Each TA1 team receiving up to 3.25 million US dollars the first year and up to 5.25 million dollars the second year;
- One TA2 team receiving up to 1.75 million US dollars each year;

Phase 2 will be 24 months long:

- Each TA1 team receiving up to 8.65 million US dollars per 12 month period;
- One TA2 team receiving up to 2 million US dollars per 12 month period;

The UHPC program technical areas are described in detail below:

TA1: UHPC System Development

Team(s) for Phases 1 and 2 will be responsible for the development of the preliminary UHPC System Design(s), execution model, and also for demonstrating the capabilities of critical technologies selected to demonstrate a viable path to achieve the program vision and goals. During Phases 3 and 4, teams will be responsible for the development of prototype UHPC Systems that achieve the UHPC program vision and goals. Across all phases, each team will develop increasingly refined execution models including power efficiency, programmability, dependability and self-aware capabilities. Capabilities will be demonstrated using simulations of the UHPC Challenge Problems, and other benchmark codes and metrics.

The proposal will describe the proposed execution model.

Proposals must describe the proposed UHPC System design, including the execution model, subcomponents and critical technologies. The proposal must address how the proposed design will address and enable the UHPC program vision and goals. The proposal must address how the proposed UHPC System will achieve the stated vision and goals, specifically efficiency, programmability, and dependability.

The proposal should describe the self-aware OS and how this system will enable efficient utilization of system resource, specifically energy, high programmability and dependability for the UHPC System.

Proposals should describe the proposed program model and the prototype compiler.

It is understood that specific challenge problem details are not provided in this solicitation, but given the general description of the challenge problem areas the proposer should describe how the proposed UHPC System will achieve the UHPC program vision and goals for the challenge problems. This should provide how high-energy efficiency, programmability and dependability are achieved given the proposed design as well as how the challenge problems described drive the proposed design. The proposal should include specifications for five application codes and data sets that are similar to the anticipated UHPC Challenge Problems. The length of the program execution time should be appropriate for the specific challenge problem. The proposal must provide estimated energy efficiency metrics (GFLOP/w for floating point intensive applications), estimated performance and time to solutions for each of the five application codes that the proposer specifies. The proposal must describe how the proposed UHPC System Design impacts programmability and dependability for the five specified applications.

The proposal must address the research and development process that will be used to investigate and modify the proposed design. It is acceptable to specify various technical approaches for some of the components or technologies within the proposed UHPC System Design. It is anticipated the proposed design will undergo many changes during the first two phases of the UHPC program. The proposal must specify how these changes will be managed so that the resulting UHPC System achieves the UHPC program vision and goals.

TA2: UHPC Applications, Benchmarks, and Metrics

During Phases 1 and 2, this team will develop metrics, benchmarks, scalable synthetic compact application codes[17] (mini-applications that are representative of a larger scale application) for the UHPC Challenge Problems, and specifications and models for five selected challenge problems (approved by DARPA) to drive the development of UHPC System Designs and aid in evaluating the systems. The TA2 team will be responsible for determining primary and additional metrics that can be used to evaluate programmability, dependability, and energy and concurrency efficiencies of the proposed prototype systems. During Phase 3, the team will develop additional benchmark codes to be used to aid DARPA in evaluating the TA1 systems. During Phase 4, the team will finalize all benchmarks to be used to aid in evaluating the final systems. The TA2 team will work closely with the TA1 teams on application development. The TA2 team will be the source for application expertise throughout the life of the UHPC program. It is required that the TA2 team includes application experts for each of the UHPC Challenge Problems. The TA2 team will pursue the interoperability of the UHPC TA1 teams' execution models and pursue the definition of a common execution model and potential standards.

[17] For examples of similar scalable synthetic compact applications see URL: http://www.highproductivity.org/SSCABmks.htm

The TA2 team proposal must include proposed specifications of the metrics, benchmarks and scalable synthetic compact applications (SSCA) codes. The proposal must describe why the proposed metrics can be used to evaluate a prototype UHPC System and demonstrate that the system will achieve the UHPC program vision and goals. The proposal must provide a proposed specification and model for each of the five challenge problems. Also, to be included is a description of why and how these problems will drive the development of a UHPC System Design.

Program Meetings

In order to achieve the program-wide collaborative research environment that will be essential to realizing the UHPC vision of reinventing computing, all UHPC performers are required to participate in Principal Investigator (PI) meetings, which will include UHPC Forum meetings.

PI meetings will be held quarterly. The DARPA program manager will set the date and location. Each PI meeting will be composed of an open session, a UHPC Forum, and an Application, Benchmark and Metrics (ABM) session. The TA2 team will lead the ABM session.

The open session will provide the opportunity for all UHPC performers to present to the open research community. UHPC PI open sessions should consist of information UHPC performers and the DARPA program manager desires to present to the open research community. Presentations from the open sessions will be posted on a publicly available web site. Speakers from outside the UHPC program may be invited to present at an open session, at the discretion of the DARPA UHPC program manager. Open and ABM sessions should be attended by a relevant subset of the project teams. The PI of each team should select the appropriate personnel to attend. It is anticipated that the open sessions will involve a significant number of team members who are involved in the UHPC research activities. The open sessions will provide an opportunity to discuss, debate, and challenge research topics that are required for the development of UHPC systems. One topic that will be included in all PI meetings, is how the proposed UHPC Systems are addressing the significant problems for future computer systems: power consumption, cyber resiliency, and user productivity.

The UHPC Forum will involve the interchange of information among the UHPC project teams as outlined in the following section. The UHPC Forum will be a closed session attended by contracted teams and their representatives and government representatives as approved by the DARPA PM. It is expected that key participants in the UHPC Forum will attend all forum meetings. The full projects' teams are not expected to attend the UHPC Forum. Presentations given at the UHPC Forum will not be submitted for public release, but will be made available to UHPC Forum participants. Presentations and prepared materials for the UHPC Forum are not expected to be formal, proof-ready documents, they are desired to be working and dynamic documents that initiate and drive innovation in support of UHPC program vision and goals. Participation in the UHPC Forum will require the acceptance of the UHPC Forum terms and condition, as described in the following sections.

Each performer will be expected to provide periodic technical and programmatic updates through bi-annual program reviews to be held at the team's facilities. The reviews will reflect an increased level of design detail and provide overall program status as well as progress toward achieving the program vision and goals and project evaluation metrics. The review should also cover updates to technological exploration, hardware/software co-design, significant design changes, benchmarks and metrics, and any other issues/concerns.

The Government also anticipates informal face-to-face technical interchange meetings (TIMs) as required over the span of the UHPC program. The objective of a TIM is to allow coordination of government objectives and contractor activities. TIMs are small working level meetings without formal documentation. Attendance at each TIM will be tailored based on the agenda. The TIMs provide an opportunity for the Government to view the progress and provide additional insight or information as required.

UHPC Forum Requirements

The fundamental vision of this program is the reinvention of computing. This can only be accomplished within an innovative, technically aggressive, and open research environment where exciting ideas, concepts, and technologies are exchanged, debated, and embraced and accelerated or disproved and rejected. In order to achieve this goal, DARPA will require its teams to participate in a program-wide collaborative research environment, called the UHPC Forum.

Definitions

UHPC Team: A team is composed of a prime who holds a contract with the government under the UHPC program and any performers under subcontract to the prime.

Intellectual Property: Creations of the mind, which include creative works or ideas embodied in a form that can be shared or can enable others to recreate, emulate, or manufacture them. There are four ways to protect intellectual property - patents, trademarks, copyrights or trade secrets.

UHPC Forum IP: Intellectual property and derivative works created as the result of the UHPC program and that will be discussed or presented in the UHPC Forum.

UHPC Project IP: Intellectual property developed by a UHPC Team using UHPC funds and the rights will not be automatically granted to the participants of the UHPC Forum.

Background IP: Intellectual property developed by a UHPC Team member that is deemed patentable or a trade secret. This is IP that was created prior to the start of the UHPC program or not utilizing UHPC funding during the lifespan of the program.

Product Plans: The details of current and future vendor products including availability dates, performance levels, and architecture features that are deemed by the developer sensitive for business reasons. Also included are implementation details concerning architectural features, and process and manufacturing details for a vendor’s products.

<u>Invention</u>: Any invention or discovery, which is or may be patentable or otherwise protectable under Title 35 of the United States Code, or any novel variety of plant, which is or may be protectable under the Plant Variety Protection Act (7 U.S.C. 2321 et seq.).

<u>Subject invention</u>: Any invention of a contractor conceived or first actually reduced to practice in the performance of work under a funding agreement; provided that in the case of a variety of plant, the date of determination (as defined in section 41(d) of the Plant Variety Protection Act, 7 U.S.C. 2401(d)) must also occur during the period of contract performance.

<u>Practical application</u>: To manufacture in the case of a composition of product, to practice in the case of a process or method, or to operate in the case of a machine or system; and, in each case, under such conditions as to establish that the invention is being utilized and that its benefits are, to the extent permitted by law or government regulations, available to the public on reasonable terms.

<u>Government Purpose Rights</u>: Rights to (i) use, modify, reproduce, release, perform, display, or disclose technical data within the Government without restriction; and (ii) release or disclose technical data outside the Government and authorize persons to whom release or disclosure has been made to use, modify, reproduce, release, perform, display, or disclose that data for United States government purposes.

<u>Government Purpose</u>:
Any activity in which the United States Government is a party, including cooperative agreements with international or multi-national defense organizations, or sales or transfers by the United States Government to foreign governments or international organizations. Government purposes include competitive procurement, but do not include the rights to use, modify, reproduce, release, perform, display, or disclose technical data for commercial purposes or authorize others to do so.

Forum Topics of Discussion

The UHPC Forum will meet at least four times a year, during the lifespan of the UHPC program. The UHPC Forum will enable cross-fertilization between the different UHPC teams - allowing each to benefit from the research results and technical approaches of the others. <u>It is expected that UHPC Forum discussions and topics will include the results of UHPC funded research on execution and programming models, methods for achieving a secure computing environment, and energy aware architectural methods and techniques for developing highly programmable computers</u>. The DARPA program manager will select the topics to be discussed during a UHPC Forum meeting. All material generated for the forum must have the appropriate markings. Topics that will not be discussed include Product Plans and Background IP not specifically authorized for discussion by the originating entity, detailed implementation concepts for the material discussed within the Forum and integrated circuit fabrication process characteristics.

Intellectual Property

It is understood that UHPC performers will have Intellectual Property (IP) that represents a competitive advantage to them within their marketplace. It is very important that the rights associated with the various types of UHPC related IP are clearly specified. There are at least four types of IP identified within the UHPC program: UHPC Forum IP, UHPC Project IP, Background IP, and Product Plans.

The following items detail the requirements concerning the UHPC related IP:

1. Any performer who presents or discusses established IP at a UHPC Forum meeting shall retain ownership of the intellectual property.
2. Performers are advised to identify and mark appropriate classifications for all documents and presentation materials.
3. Concepts or technologies that are presented or discussed in the UHPC Forum, the performer must declare, in a timely manner, their intent to establish ownership as IP or state they do not intend to establish as IP.
4. UHPC Forum IP will not include any performer's Background IP.
5. A UHPC performer, for reasons of competitive advantage, might determine that UHPC Project IP will not be shared openly with the UHPC community. It is the responsibility of a performer to define, protect, and safeguard its UHPC Project IP.
6. The Government shall be granted unlimited rights to all UHPC Forum IP.
7. All concepts and technologies presented or discussed in the UHPC Forum that are not UHPC Project IP, Background IP and Product Plans can be freely discussed and published outside of the forum.
8. The results of the collaborative research, as well as all other information, materials, etc. that the performers exchange to facilitate the research, will be provided without warranty.
9. It is possible that part of or all of the technology utilized to develop the prototype UHPC system will eventually be integrated into a vendor's future products. Therefore the prototype system and UHPC System Design will be considered to be Product Plans.
10. The details concerning Background IP and Product Plans that are relevant to the UHPC program will be presented and discussed at Government-only meetings.
11. The Government shall have "Government Purpose Rights" to all IP developed and funded by the UHPC program, except for UHPC Forum IP.
12. <u>All UHPC team members, under prime contract and subcontract, will be bound by the agreements contained in the prime contract.</u>

Limitations on the use of the IP that is presented or discussed in the Forum may diminish the value of a discussion to the performers and result in limited participation and value.

Performers must include documentation proving ownership or possession of appropriate licensing rights to all patented inventions (or inventions for which a patent application has been filed) that will be utilized under the proposal for the UHPC program. If a patent application has been filed for an invention that your proposal utilizes, but the application has not yet been made publicly available and contains proprietary information, you may provide only the patent number, inventor name(s), assignee names (if any), filing date, filing date of any related provisional application, and a summary of the patent title, together with either:

- A representation that you own the invention, or
- Proof of possession of appropriate licensing rights in the invention to meet the Government's needs as envisioned at the start of this guidance.

Performers must indicate patents for developmental, experimental, and research components created or modified specifically under the UHPC program and significant background patents.

During the scientific review process, the Government must have a clear and detailed understanding from the contractor's written proposal of the existence and nature of all applicable intellectual property-based restrictions or limitations, as well as any other restrictions and limitations, on the proposed UHPC System Design and supporting technologies. Proposers should clearly explain how such restrictions and limitations would affect UHPC Forum IP. Deficiencies in proposals that do not contain a sufficiently detailed and clear disclosure and explanation of the existence and effects of all such restrictions and limitations will likely be reflected in evaluation scoring during the scientific review process.

During Phases 1 and 2 all UHPC participants, including universities and small businesses, are strongly encouraged to retain sufficient rights to the technologies that they have developed under this program. In future phases this will enable participants to transition between teams.

This information will be summarized in the UHPC IP Lineage Document. This document must specify all IP that is utilized in a team's UHPC System Design. This document will be updated throughout the lifespan of the program. The document will provide a clear description of the IP, the ownership, licensees and rights associated with the IP.

UHPC Forum Participation

The UHPC Forum will involve the interchange of information among the UHPC project teams as outlined in the UHPC Forum Requirements section. The UHPC Forum will be a closed session attended by contracted teams and their representatives and Government representatives as approved by the DARPA PM. It is expected that key participants in the UHPC Forum will attend all forum meetings. All performers will need to either (1) agree to Forum participation as described in the UHPC Forum Requirements, or (2) clearly articulate their approach to address the sharing of contractually developed concepts and research that will still meet DARPA's goal of making selected UHPC program developed concepts and research freely available for discussion within the UHPC community. If the proposer's submission includes another way to address the sharing of UHPC developed concepts and research other than participation in the UHPC Forum and per the UHPC Forum Requirement that will still satisfy the government requirements, the government will consider this approach during the evaluation. A more favorable evaluation will be given to those proposals that do not constrain or limit sharing of contractually developed concepts and research within the UHPC community. It is anticipated that the UHPC Forum Requirement and participation in the UHPC Forum will provide the best path to achieving this goal.

Team Structure Transition Strategy

TA1 teams are expected to address the vision and goals of the UHPC program. However, it is recognized that the industrial and university components of a team may change from phase to phase. Each team is encouraged to pursue the best, innovative approaches. This may involve changes to a team. Reteaming is the responsibility of the vendor and university entities. Teams will be reviewed by DARPA based solely on their ability develop a UHPC System that will achieve the UHPC vision and goals and innovativeness in advancing computing system capabilities. The DARPA PM will review all proposed team changes and will either approve or reject the changes.

DARPA envisions Phases 1 and 2 of the proposed UHPC program under one solicitation and Phases 3 and 4 will be addressed under separate solicitations. If Phases 3 and 4 are warranted, DARPA anticipates a limited solicitation for the TA1 teams and an open solicitation for the TA2 team. For TA1 teams, Phases 3 and 4 will be based on the preliminary designs that are developed in Phase 2. UHPC teams submitting proposals to the anticipated Phase 3/4 solicitation must certify and demonstrate that they have the full rights to the proposed UHPC System Design, including the UHPC Project IP and Background IP that will be required to build the prototype system. Changes or improvements to these designs must be justified using an appropriate level of analysis that will include results that show the impact of these changes on the ability to achieve the UHPC program vision and goals. DARPA acknowledges that the composition of TA1 teams who submit proposals for Phases 3 and 4 may be different than the teams that developed the preliminary designs in Phases 1 and 2; however, a potential critical evaluation criterion will be the ability of the proposed Phase 3/4 team to complete the proposed design and build the system. Maintaining open innovation through the life of this program is a requirement.

Detailed Technical Area Descriptions

TA1: UHPC System Development

DARPA seeks systems that will achieve the UHPC program vision and goals. The UHPC Challenge Problems will drive the development of the UHPC System.

To overcome the energy challenge, a new system-wide approach must be developed to minimize energy dissipation per operation, with a 50 GFLOPS per watt goal for the HPL benchmark. It is desirable that this be accomplished without sacrificing the scalability to support ultra-high performance DoD applications. To overcome the programmability challenge, new technologies must be developed that do not require application programmers to explicitly manage the system complexity or be a system expert to achieve their performance and time to solution goals. The application programmer should not need to be knowledgeable in terms of architectural attributes such as data locality and concurrency. UHPC System Designs must address a means to expose and manage hardware and software concurrency, minimizing overhead for thousand-way to billion-way parallelism for the system-level programmer. A UHPC System Design must incorporate dependability at all levels, including embedded hardware capabilities. To overcome the dependability challenge a system–wide approach must be developed to provide prevention, detection, and response to attacks and faults.

A high-level representation of the scalability of the UHPC system is shown in Figure 4.

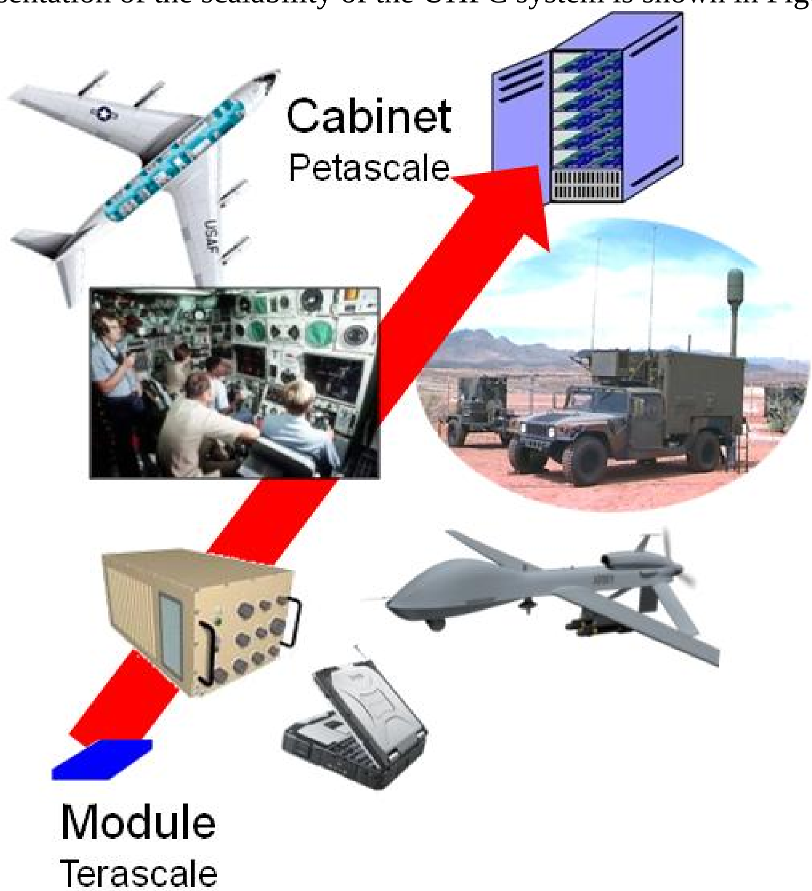

Figure 4 - UHPC System Scalability

As represented in Figure 4, a UHPC module could be used in an embedded terascale application or assembled to form a cabinet level system to support petascale applications. It is envisioned that, from the module up, each level should have stand-alone capability and be usable in a variety of DoD systems. At each stage, teams will need to show that theirs is an innovative approach and show a viable path, through critical technology demonstrations, system level analysis, and sub-system and system level simulations, to prove that the team can reach the overall system goals. This will incorporate the development of architectures, execution models, operating systems, secure and dependable approaches, and self-aware techniques.

The TA1 teams must clearly address their design approach and principles. A static design or designs composed of strictly evolutionary components will not be accepted. Proposals must identify the revolutionary approaches and concepts in the design. The proposed UHPC System Design and a significant number of the technologies utilized in the design are required to be revolutionary. Investigation and discovery of revolutionary approaches and technology is expected. Development, advancement, and maturity of these technologies are to be proposed and performed through the evolution of program in phases 1 and 2. A strong plan for the development, evaluation, and incorporation of technologies should be proposed.

An initial UHPC system approach is to be proposed for Phase 1, with development, refinement, and the validation of the ability to achieve the UHPC goals proposed in Phase 2. The proposed initial system approach must establish the conceptual framework, expectations, and constituent components. To achieve the UHPC program vision and goals all layers of the initial system need to be addressed – what they are and how they interact, function, and individually and collectively. As with the proposed system layers, critical proposed technology component development must clearly detail how they will be pursued, evaluated, function, interact, and individually and collectively. The development approach, expected risks, and anticipated results of the proposed technology developments must be sufficiently detailed. The interplay of the proposed technical developments and innovation against the UHPC program vision and goals must be explained in detail.

The cross cutting principles of dependability, energy efficiency, and programmability/usable concurrency need to be addressed in the proposed initial system concept and pursued throughout prototype system development. The approach to accomplish this must be clearly described in the proposal. Proposed system concepts cannot be judged by guarantees of key technology development success, but on the proposed advancement of technology at the critical system component and integrated system level. An understanding of the risk and probability of success, a viable plan for technology application and how proposed technology developments will be integrated into overall system conceptual design development must be provided.

TA1 teams must describe how their research and design process will utilize open innovation throughout the life of the program.

PI meetings and program reviews will reflect an increasing level of design detail and provide overall program status as well as progress toward achieving the program vision goals. PI meetings and program reviews should also cover updates to technological exploration, hardware/software co-design, significant design changes, and any issues/concerns. Each team must present the design trade-offs that determine UHPC System Design direction, selection and the impact on the UHPC program goals.

Technical evaluations of TA1 teams will occur prior to the beginning of Phase 2. Advancing to Phase 2 will be based on factors that include demonstration of achieving open innovation, progress toward UHPC program vision and goals, overall design, and the availability of funds.

TA1 Phases, Metrics and Deliverables

<u>Phase 1 Overview:</u> Preliminary execution model, initial critical technology simulations, initial UHPC System Design and simulation demonstrating viable path toward the program goals.

Phase 1 will deliver a conceptual UHPC System Design document, including a preliminary execution model, for the proposed UHPC system. The system conceptual design developed in Phase 1 should be based on truly transformational technologies and "out of the envelope" thinking. The designs should allow for consideration and insertion of novel and developmental technologies, which will be further, developed and evaluated for validity in Phase 2. Innovative technical approaches achieving energy efficiency, programmability, and dependability must be clearly shown within the deliverables. Each team shall provide an analysis of the proposed UHPC System that validates their ability to achieve program goals.

In Phase 1, each TA1 team will deliver the following documents: UHPC Design, non-UHPC Critical Technologies and Subsystems, UHPC Test Plan, UHPC Benchmark and Metric and UHPC IP Lineage. The novel and transformational technologies considered shall be evaluated, their validity determined, and as appropriate inserted into the initial UHPC System Design or terminated. The UHPC Design document will include the initial execution model and the system architecture. This document must include sufficient technical detail for DARPA to be able to evaluate the proposed system. This shall include initial technology exploration and system simulation results. Simulations will incorporate critical technology explorations results, including design elements such as hardware/software interfaces and protocols. The system impact, in terms of energy efficiency, programmability, and dependability must be clearly provided within the deliverables. Each team will provide an analysis and initial simulations/emulations of the proposed system that validates their ability to achieve program goals. This includes critical technology assessments. Another UHPC deliverable is a document that specifies all IP that is utilized in a team's UHPC System Design, including all UHPC Project IP, what type of IP it is, and who retains the rights to any declared IP. This document will be updated throughout the lifespan of the program. The document will provide a clear description of the IP, the ownership, licensees and rights associated with the IP. This document is called "UHPC IP Lineage".

<u>Phase 1 Deliverables:</u> The deliverable is a comprehensive report that includes the following documents. These documents, plus additional briefing materials, will be presented and reviewed at the Conceptual Design Review (CoDR), which will be held at the end of the first year of Phase 1.

- [UHPC Design Document, v1] A UHPC System Design document with sufficient detail to evaluate the viability of the proposed system approach/design. This document must include:
  - Proposed execution model, including justification for the proposed execution model;
  - High level description of proposed UHPC System Design, including sufficient technical detail to qualitatively evaluate the proposed system;
  - Detailed description of the hardware and software components in the proposed UHPC System Design, including sufficient technical detail to qualitatively evaluate the proposed components;
  - Analytical analysis of the proposed system, critical subsystems and components performance;
  - System dependability model, including plans for verifying the model;

- Critical technologies that are required in the UHPC System Design, but not developed under the UHPC program.
- Detailed analytical information that demonstrates the ability of the proposed UHPC System to achieve the UHPC program vision and goals;
- Initial simulations or emulations of critical technologies, subsystems, and UHPC System Design;
- Detailed description of how the UHPC Challenge Problems impact the proposed design and the projected performance, energy efficiency and other metrics;
- Description of the methodology of the performed system related or application simulations; and
- CoDR briefing materials.

* [Non-UHPC Critical Technologies and Subsystems Document, v1] Details for all non-UHPC developed critical technologies, subsystems and components that will be utilized in the proposed UHPC system, including acquisition plans, risk assessment and risk reduction plans for each technology. This document must include:
  - Detailed description of the proposed fundamental critical technologies and subsystems that are to be used in the UHPC system, which will not be developed under this program. An example of a proposed critical technology is a non-volatile memory device that is to be used in the system node. An example of a critical subsystem is a storage subsystem that might be manufactured by a storage vendor in the UHPC System timeframe. An example of a software component is the file system;
  - Detailed description of how these technologies, subsystems and components will be integrated in the UHPC System Design. Specifically the description should include the interfaces between the item and the proposed system;
  - Technology development and acquisition road map; and
  - A risk reduction plan associated with each critical technologies, subsystems and components.
* [UHPC Test Plan Document, v1] A plan for the analysis, initial simulations, and evaluations to be performed.
* [UHPC Benchmark and Metric Document, v1] Provides results based on simulation for the UHPC benchmarks and Metrics and UHPC application performance models. This document must include the performance model results of the five UHPC Challenge Problems, and fully document the application performance modeling methodology.
* [UHPC IP Lineage Document, v1] This document will provide a clear description of all UHPC Project IP, the ownership, licensees and rights associated with the IP.

<u>Phase 1 Program Evaluation Metrics:</u> There will be three qualitative program evaluations based on proposed system analysis.

The first qualitative evaluation will be based on the UHPC conceptual design document described above, including the preliminary execution model and preliminary system simulations.

The second qualitative evaluation will be based on the non-UHPC Critical Technologies and Subsystems document described above. The third qualitative evaluation will be the Conceptual Design Review (CoDR). DARPA will evaluate these documents and the review.

Phase 2 Overview: Preliminary UHPC System Design, preliminary hardware and software technologies demonstrations, full system simulation, and evaluation of the UHPC Preliminary Design Review (PDR).

In Phase 2, each TA1 team will deliver a preliminary design and the validation of the proposed system that must include sufficient technical detail for DARPA to evaluate the proposed system. This shall include architecture, execution model, preliminary technologies, critical subsystems, and system simulation/emulation and critical technologies demonstrations results. Simulations will incorporate critical technology results, including design elements such as hardware/software interfaces and protocols. Simulations/emulations must be capable of running UHPC prototype system software. Innovativeness and system impact, in terms of performance, programmability, and dependability must be clearly shown within the deliverables. Each team will provide an analysis and simulations/emulations of the proposed system that validates their ability to achieve program vision and goals. During this phase, the TA1 teams will provide performance models for the UHPC Challenge Problems. DARPA will assess the innovativeness, strengths, and limitations of each UHPC TA1 team's overall design.

Phase 2 Deliverables: The deliverable is a comprehensive report that includes demonstrations and updated versions of the following documents. These documents, plus additional PDR briefing materials, will be presented and reviewed at the PDR, which will be held two calendar quarters before the end of Phase 2.

- [UHPC Design Document, v2] A comprehensive preliminary UHPC System Design document with sufficient detail to evaluate the viability of the proposed system approach/design. This will be based on simulations of the proposed system, including critical subsystems, components, and technologies. This will also be based on the simulation of the SSCA codes. This document will provide an update to the Phase 1 version of this document and must also include:
  - Critical components and subsystems demonstrations results and the impact on the UHPC System Design;
  - Identification of the high-risk components in the design and a risk reduction plan for each identified component;
  - Detailed UHPC System development plan and schedule; and
  - PDR briefing materials.
- [Non-UHPC Critical Technologies and Subsystems Document, v2] Details for all non-UHPC developed critical technologies, subsystems and components that will be utilized the proposed UHPC system, including acquisition plans, risk assessment and risk reduction plans for each technology.
- [UHPC Demonstrations] Preliminary hardware and software technologies demonstrations, including prototype system software components. This should include a detailed description

of how the technologies are incorporated into the UHPC System Design and resulting performance.

- [UHPC Test Plan Document, v2] A plan for simulations, critical component and subsystem demonstrations and performance evaluations to be performed within this phase.
- [UHPC Benchmark and Metric Document, v2] Provides results based on simulation for the UHPC benchmarks and Metrics and UHPC application performance models. This document must include the results of the performance modeling of the UHPC Challenge Problems and fully document the performance modeling methodology.
- [UHPC IP Lineage Document, v2] This document will provide a clear description of all UHPC Project IP, the ownership, licensees and rights associated with the IP.

Phase 2 Program Evaluation Metrics: There will be five program evaluations based on proposed UHPC system analysis.

The first evaluation will be based on the preliminary UHPC System Design documents including the execution model. The second evaluation will be based on the non-UHPC Critical Technologies and Subsystems document. The third is the documented results of the UHPC demonstrations. DARPA will evaluate these documents. The fourth evaluation metric will be based on the results of the simulation of the UHPC benchmarks and metrics to include those developed by the TA2 team. The fifth evaluation metric will be the PDR. DARPA will determine if a TA1 team has successfully completed its PDR.

TA1 UHPC Development Teams	Phase Results
Phase 1: 24 Months 5 Teams - University and Industry participation	• Conceptual and initial system designs, including the initial execution model. • Non-UHPC Critical Technologies and Subsystems. • Analysis and initial simulations/emulations of the proposed systems. • Architectural review and analysis for downselect.
Phase 2: 24 months 3 Teams - University and Industry participation	• Preliminary design and validation of the proposed system • Simulations/emulations capable of running UHPC prototype system software. • Preliminary design review.
Phases 3 & 4: 3 Teams – Industry lead with continuing University innovation	• Proposals will be submitted for selection of designs for Phases 3 and 4 • Build prototype UHPC systems, including software. • Demonstrate program goals.

Table 2 - UHPC Technical Area 1 Program Elements

TA2: UHPC Applications, Benchmarks and Metrics

A single TA2 team will be selected to develop metrics, benchmarks, and SSCA codes to be coordinated with the TA1 teams. The metrics, benchmarks, and SSCA codes will be proposed to and approved by DARPA. The metrics developed will provide the evaluation of programmability, dependability, performance, energy and concurrency efficiency and other UHPC System characteristics. The TA2 team will develop benchmarks based on the Streaming Sensor Data, Dynamic Graph, and Decision challenge problems and two additional significant DoD applications to be selected by DARPA. The TA2 team might propose other benchmark codes that are not directly related to the UHPC Challenge Problems. The TA2 team will coordinate the development and distribution of the metrics, benchmarks, and SSCA codes with the TA1 teams. It is assumed that these codes provide a reference implementation of the metrics, benchmarks and SSCA codes for the TA1 teams. TA1 teams can rewrite these reference implementations based on the proposed programming model for their UHPC System.

The TA2 team is expected to participate throughout the first two phases of this program. Continuation of this TA2 team will depend on such factors as the quality of the metrics, benchmarks, SSCA codes, and other factors determined by DARPA. Continuation of TA2 is contingent on the decision to proceed with ongoing TA1 activities among other programmatic considerations.

The TA2 team will be the source of application expertise for the UHPC program. This team should consist of experts in the development of large-scale applications, modeling and simulation, and computer architectures. The TA2 team should have expertise in areas related to the UHPC Challenge Problems, and other representative DoD applications.

The PI meetings and program reviews will reflect an increasing maturity of metrics, benchmarks and the specifications and models for the UHPC Challenge Problems. DARPA expects a sufficient level of detail in specification and models of the UHPC Challenge Problems.

The TA2 team will be expected to share details of their activities in the UHPC Forum. The TA2 team will hold open UHPC community wide meetings as part of UHPC PI meetings. These meetings will be used to enable the distribution and coordination of the metrics, benchmarks, and SSCA codes developed and to develop UHPC wide standards.

The specifications and software for the UHPC Challenge Problems, SSCA codes, benchmark codes and metrics will be released as open source. The TA2 team must provide a website to make the UHPC Challenge Problem specifications and models, and software and data sets available.

TA2 Phases, Metrics, and Deliverables

<u>Phase 1 Overview:</u> Provide the definition, development, and delivery of initial metrics, and benchmarks. Provide the specification and models of the UHPC Challenge Problems, and five SSCA codes based on the UHPC Challenge Problems. The TA2 team will coordinate the above with the TA1 teams. The TA2 team will pursue the definition and development of common standards and interfaces for the UHPC community.

During Phase 1, the TA2 team will provide the specification and models for the UHPC Challenge problems, including the selection of two DoD applications (approved by DARPA). The TA2 team will provide the initial specification and models of the five challenge problems to the TA1 teams six months after the initiation of the TA2 contract. The challenge problems descriptions and specifications will have a sufficient level of detail for the TA1 teams to use the information to drive the development of their UHPC System Designs.

The TA2 team will propose and develop a set of metrics, benchmarks, and SSCA codes to be approved by DARPA, for distribution to the TA1 teams. The TA2 team will support the distribution of the metrics, benchmarks, and SSCA codes to the TA1 teams. The TA2 team must provide documentation of the metrics, benchmarks, and SSCA codes that will be provided to the TA1 teams. Proposed metrics shall include energy, concurrency, programmability, dependability, I/O, and other metrics with appropriate targets.

The TA2 team will develop and provide a methodology and schedule for the selection and development of metrics, benchmarks, and SSCA codes. The DARPA Program Manager will review and approve the proposed metrics and development schedule.

Phase 1 Deliverables:

- [UHPC Challenge Problems Specification Document, v1] This document will provide the specifications and models for the five UHPC Challenge Problems and the design of the SSCA codes. The initial UHPC Challenge Problem specifications and models will be delivered six months after contract initiation.
- [UHPC Test Suite, v1] This deliverable will include all source code for evaluating the metrics, benchmarks and SSCAs. Where appropriate, a high level programming language version of a software item will be provided (for example a MATLAB version) and a lower level programming language version of a software item will be provided (for example written the C language). The test suite will also include all required data sets or software for generating the data sets.
- [TA1 UHPC Document(s), v1] User documentation for the initial metrics, benchmarks, and SSCA codes found in the UHPC Test Suite. This document will be distributed to TA1 teams.
- [UHPC Metric and Benchmarks Document, v1] This document will provide information concerning the proposed metrics and benchmarks.
- [UHPC Development Plan, v1] This document will provide the methodology and schedule for the development and distribution of the UHPC Test Suite, v1.

Phase 1 Program Evaluation Metrics: The successful completion and evaluation of all Phase 1 deliverables.

Phase 2 Overview: Final metrics, benchmarks, SSCA codes will be based on the five challenge problems. The TA2 team will continue to coordinate the above with the TA1 teams and final definition of common standards.

During Phase 2, the TA2 team will continue the refinement of the specifications and deliver the final models for the five UHPC Challenge Problems. The TA2 will provide final sets of metrics, benchmarks, and SSCA codes to be approved by DARPA, for distribution to the TA1 teams. The specifications will have a sufficient level of detail for the TA1 teams to use the information to continue to drive the development of their UHPC System Designs. The TA2 team will deliver the metrics, benchmarks, and SSCA codes per updated schedule provided in Phase 1. TheTA2 team must provide final documentation of the metrics, benchmarks, and scalable application provided to the TA1 teams.

Phase 2 Deliverables:

- [UHPC Challenge Problems Specification Document, v2] This document will provide final specifications for the five UHPC Challenge Problems and the design of the SSCA codes.
- [UHPC Test Suite, v2] Final release of the test suite.
- [TA1 team UHPC Document(s), v2] Final documentation for the metrics, benchmarks, and SSCA codes in the UHPC Test Suite.
- [UHPC Metric and Benchmarks Document, v2] This document will provide updated information concerning the final metrics and benchmarks. This document will be developed in a format to be provided as an open source to the community.
- [UHPC Development Plan, v2] This document will provide the methodology and schedule for the development and distribution of the metrics, benchmarks, and SSCA codes.

Phase 2 Program Evaluation Metrics:

- The successful completion and evaluation of all Phase 2 deliverables.

TA2 team selection for Phases 3/4 will be based on an open solicitation.

TA2 UHPC Applications, Benchmarks, and Metrics Team	Phase Results
Phases 1 - 4	• Develop the model and specifications for the UHPC Challenge Problems to drive UHPC designs • Develop the SSCA codes • Develop benchmarks and metrics for evaluating performance • Organize and coordinate cooperative forum incorporating design teams to develop and distribute common standards and references

Table 3 - UHPC Technical Area 2 Program Elements

Teaming and Collaboration

DARPA strongly encourages teams that fully address the set of technologies required to overcome all challenge areas discussed above and that can achieve UHPC program vision and goals. These teams must provide demonstrated experience in all required technology areas. TA1 team expertise should include: energy efficiency, massive resource concurrency, data location and movement, dependability, self-aware operations, execution models, operating system, compiler design, simulation/emulation development, the ability to program and effectively utilize system resources as one integrated UHPC System Design, and experience interrupting applications as they relate to computer UHPC System Design and evaluation. TA1 team participants should be drawn from both academic and industrial communities. It is expected that both communities will be involved in all aspects of the UHPC program throughout all four phases of the UHPC program.

TA2 team expertise should include: extensive knowledge of the challenges encountered when developing ExtremeScale systems, DoD applications, the five UHPC Challenge Problems, and metrics, benchmark, and SSCA development. It is a requirement that the TA2 team be composed of leading experts for the five UHPC Challenge Problems. The TA1 teams will rely on the TA2 UHPC Challenge Problems expertise. The TA2 team will lead the ABM meetings. Therefore the leadership of the TA2 must have proven experience managing similar meetings.

The goal of multi-discipline teaming is to achieve faster progress by creating a critical mass of innovative, relevant expertise. While DARPA expects strong, multidisciplinary teams, each team must be lead by a single principal investigator. Both TA1 and TA2 team principal investigators must demonstrate a proven track record of working with and productively managing diverse, academic/industrial groups. DARPA expects each team to submit a single, unified proposal. Subcontractors should not submit separate proposals.

II. AWARD INFORMATION

Multiple awards are anticipated for TA1 and a single award for TA2. The amount of resources made available to this BAA will depend on the quality of the proposals received and the availability of funds. Proposals identified for negotiation may result in a procurement contract or other transaction depending upon the nature of the work proposed, the required degree of interaction between parties, and other factors. Awards under this BAA will be made to proposers on the basis of the evaluation criteria listed below (see section V - Application Review Information), and program balance to provide overall value to the Government.

In addition, the Government reserves its rights to the following:

- To select for negotiation all, some, one, or none of the proposals received in response to this solicitation;
- To make awards without discussions with proposers;
- To conduct discussions if it is later determined to be necessary;
- To segregate portions of resulting awards into pre-priced options;
- To accept proposals in their entirety or to select only portions of proposals for award;
- To fund proposals in phases with options for continued work at the end of one or more of the phases;
- To request any additional, necessary documentation once it makes the award instrument determination; such additional information may include but is not limited to Representations and Certifications; and
- To remove proposers from award consideration should the parties fail to reach agreement on award terms, conditions and cost/price within a reasonable time or the proposer fails to timely provide requested additional information.

As of the date of publication of this BAA, DARPA expects that program goals for this BAA may be met by proposers intending to perform 'fundamental research,' i.e., basic and applied research in science and engineering, the results of which ordinarily are published and shared broadly within the scientific community, as distinguished from proprietary research and from industrial development, design, production, and product utilization the results of which ordinarily are restricted for proprietary or national security reasons. Notwithstanding this statement of expectation, DARPA is not prohibited from considering and selecting research proposals that, while perhaps not qualifying as 'fundamental research' under the foregoing definition, still meet the BAA criteria for submissions. In all cases, the contracting officer shall have sole discretion to select award instrument type and to negotiate all instrument provisions with selectees.

III. ELIGIBILITY INFORMATION

A. Eligible Applicants

All responsible sources capable of satisfying the Government's needs may submit a proposal that shall be considered by DARPA. Historically Black Colleges and Universities (HBCUs), Small Businesses, Small Disadvantaged Businesses and Minority Institutions (MIs) are encouraged to submit proposals and join others in submitting proposals; however, no portion of this announcement will be set aside for these organizations' participation due to the impracticality of reserving discrete or severable areas of this research for exclusive competition among these entities.

Federally Funded Research and Development Centers (FFRDCs) and Government entities (Government/National laboratories, military educational institutions, etc.) are subject to applicable direct competition limitations and cannot propose to this BAA in any capacity unless they meet the following conditions. FFRDCs must clearly demonstrate that the work is not otherwise available from the private sector AND they also provide a letter on letterhead from their sponsoring organization citing the specific authority establishing their eligibility to propose to government solicitations and compete with industry, and compliance with the associated FFRDC sponsor agreement and terms and conditions. This information is required for FFRDCs proposing to be prime or subcontractors. Government entities must clearly demonstrate that the work is not otherwise available from the private sector and provide written documentation citing the specific statutory authority (as well as, where relevant, contractual authority) establishing their ability to propose to Government solicitations. At the present time, DARPA does not consider 15 U.S.C. 3710a to be sufficient legal authority to show eligibility. While 10 U.S.C. 2539b may be the appropriate statutory starting point for some entities, specific supporting regulatory guidance, together with evidence of agency approval, will still be required to fully establish eligibility. DARPA will consider eligibility submissions on a case-by-case basis; however, the burden to prove eligibility for all team members rests solely with the Proposer.

Foreign participants and/or individuals may participate to the extent that such participants comply with any necessary Non-Disclosure Agreements, Security Regulations, Export Control Laws, and other governing statutes applicable under the circumstances.

Applicants considering classified submissions (or requiring access to classified information during the life-cycle of the program) shall ensure all industrial, personnel, and information system processing security requirements are in place and at the appropriate level (e.g., Facility Clearance (FCL), Personnel Security Clearance (PCL), certification and accreditation (C&A)) and any Foreign Ownership Control and Influence (FOCI) issues are mitigated prior to such submission or access. Additional information on these subjects can be found at: www.dss.mil.

1. Procurement Integrity, Standards of Conduct, Ethical Considerations, and Organizational Conflicts of Interest

Current federal employees are prohibited from participating in particular matters involving conflicting financial, employment, and representational interests (18 USC 203, 205, and 208.). The DARPA Program Manager for this BAA is Dr. William Harrod.

Once the proposals have been received, and prior to the start of proposal evaluations, the Government will assess potential conflicts of interest in regards to the DARPA Program Manager, as well as those individuals chosen to evaluate proposals received under this BAA, and will promptly notify the proposer if any appear to exist. (Please note the Government assessment does NOT affect, offset, or mitigate the proposer's own duty to give full notice and planned mitigation for all potential organizational conflicts, as discussed below.)

All proposers and proposed subcontractors must affirm whether they are providing scientific, engineering, and technical assistance (SETA) or similar support to any DARPA technical office(s) through an active contract or subcontract. All affirmations must state which office(s) the proposer supports and identify the prime contract numbers. Affirmations shall be furnished at the time of proposal submission. All facts relevant to the existence or potential existence of organizational conflicts of interest (FAR 9.5) must be disclosed. The disclosure shall include a description of the action the proposer has taken or proposes to take to avoid, neutralize, or mitigate such conflict. In accordance with FAR 9.503 and without prior approval or a waiver from the DARPA Director, a Contractor cannot simultaneously be a SETA and Performer. Proposals that fail to fully disclose potential conflicts of interests and/or do not have plans to mitigate this conflict will be rejected without technical evaluation and withdrawn from further consideration for award.

If a prospective proposer believes that any conflict of interest exists or may exist (whether organizational or otherwise), the proposer should promptly raise the issue with DARPA by sending the proposer's contact information and a summary of the potential conflict by email to the mailbox address for this BAA at DARPA-BAA-10-37@darpa.mil, before time and effort are expended in preparing a proposal and mitigation plan. If, in the sole opinion of the Government after full consideration of the circumstances, any conflict situation cannot be effectively mitigated, the proposal may be rejected without technical evaluation and withdrawn from further consideration for award under this BAA.

B. Cost Sharing or Matching

Cost sharing is not required for this particular program; however, cost sharing will be carefully considered where there is an applicable statutory condition relating to the selected funding instrument (e.g., for any Technology Investment Agreement under the authority of 10 U.S.C. 2371). Cost sharing is encouraged where there is a reasonable probability of a potential commercial application related to the proposed research and development effort.

C. Other Eligibility Criteria

1. Collaborative Efforts

Collaborative efforts/teaming are encouraged. See Page 39 of this document for more information on Teaming and Collaboration.

IV. *__APPLICATION AND SUBMISSION INFORMATION__*

A. Address to Request Application Package

This solicitation contains all information required to submit a proposal. No additional forms, kits, or other materials (other than those noted within this document) are needed. This notice constitutes the total BAA. No additional information is available, nor will a formal Request for Proposal (RFP) or additional solicitation regarding this announcement be issued. Requests for same will be disregarded.

B. Content and Form of Application Submission

1. Security and Proprietary Issues

NOTE: If proposals are classified, the proposals must indicate the classification level of not only the proposal itself, but also the anticipated award document classification level.

The Government anticipates proposals submitted under this BAA will be unclassified. However, if a proposal is submitted as "Classified National Security Information" as defined by Executive Order 12958 as amended, then the information must be marked and protected as though classified at the appropriate classification level and then submitted to DARPA for a final classification determination.

Proposers choosing to submit a classified proposal from other classified sources must first receive permission from the respective Original Classification Authority in order to use their information in replying to this BAA. Applicable classification guide(s) should also be submitted to ensure the proposal is protected at the appropriate classification level.

Classified submissions shall be appropriately and conspicuously marked with the proposed classification level and declassification date. Submissions requiring DARPA to make a final classification determination shall be marked as follows:

CLASSIFICATION DETERMINATION PENDING - Protect as though classified (insert the recommended classification level: e.g., Top Secret, Secret, or Confidential)

Classified submissions shall be in accordance with the following guidance:

__Confidential and Secret Collateral Information:__ Use classification and marking guidance provided by previously issued security classification guides, the Information Security Regulation (DoD 5200.1-R), and the National Industrial Security Program Operating Manual (DoD 5220.22-M) when marking and transmitting information previously classified by another Original Classification Authority. Classified information at the Confidential and Secret level may be mailed via appropriate U.S. Postal Service methods (e.g., (USPS) Registered Mail or USPS Express Mail). All classified information will be enclosed in opaque inner and outer covers and double wrapped. The inner envelope shall be sealed and plainly marked with the assigned classification and addresses of both sender and addressee. The inner envelope shall be addressed to:

Defense Advanced Research Projects Agency
ATTN: TCTO
Reference: DARPA-BAA-10-37
3701 North Fairfax Drive
Arlington, VA 22203-1714

The outer envelope shall be sealed with no identification as to the classification of its contents and addressed to:

Defense Advanced Research Projects Agency
Security & Intelligence Directorate, Attn: CDR
3701 North Fairfax Drive
Arlington, VA 22203-1714

All Top Secret materials: Top Secret information should be hand carried by an appropriately cleared and authorized courier to the DARPA CDR. Prior to traveling, the courier shall contact the DARPA CDR at (571) 218-4842 to coordinate arrival and delivery.

Special Access Program (SAP) Information: SAP information must be transmitted via approved methods. Prior to transmitting SAP information, contact the DARPA SAPCO at 703-526-4052 for instructions.

Sensitive Compartmented Information (SCI): SCI must be transmitted via approved methods. Prior to transmitting SCI, contact the DARPA Special Security Office (SSO) at 703-248-7213 for instructions.

Proprietary Data: All proposals containing proprietary data should have the cover page and each page containing proprietary data clearly marked as containing proprietary data. It is the proposer’s responsibility to clearly define to the Government what is considered proprietary data.

Security classification guidance via a DD Form 254 will not be provided at this time since DARPA is soliciting ideas only. After reviewing the incoming proposals, if a determination is made that the award instrument may result in access to classified information, a DD Form 254 will be issued and attached as part of the award.

Proposers must have existing and in-place prior to execution of an award, approved capabilities (personnel and facilities) to perform research and development at the classification level they propose. It is DARPA’s policy to treat all proposals as competitive information, and to disclose their contents only for the purpose of evaluation. Proposals will not be returned. The original of each proposal received will be retained at DARPA and all other non-required copies destroyed. A certification of destruction may be requested, provided the formal request is received at this office within five days after unsuccessful notification.

2. Proposal Information

Proposers are required to submit full proposals by the time and date specified in the BAA in order to be considered during the initial round of selections. DARPA may evaluate proposals received after this date for a period up to 180 days from date of posting on FedBizOpps. Ability to review late submissions remains contingent on availability of funds.

The typical proposal should express a consolidated effort in support of one or more related technical concepts or ideas. Disjointed efforts should not be included into a single proposal.

Restrictive notices notwithstanding, proposals may be handled, for administrative purposes only, by a support contractor. This support contractor is prohibited from competition in DARPA technical research and is bound by appropriate non-disclosure requirements. Proposals may not be submitted by fax or e-mail; any so sent will be disregarded.

Proposals not meeting the format described in the BAA may not be reviewed.

All administrative correspondence and questions on this solicitation, including requests for information on how to submit a proposal to this BAA, should be directed to the administrative addresses below; e-mail or fax is preferred.

- EMAIL: DARPA-BAA-10-37@darpa.mil
- FAX: (703) 465-8096
- ATTN: DARPA-BAA-10-37
  3701 North Fairfax Drive
  Arlington, VA 22203-1714

DARPA intends to use electronic mail and fax for correspondence regarding DARPA BAA 10-37. Proposals may not be submitted by fax or e-mail; any so sent will be disregarded. DARPA encourages use of the Internet for retrieving the BAA and any other related information that may subsequently be provided.

DARPA will employ an electronic upload submission system (T-FIMS) for all unclassified responses to this BAA. Proposals sent in response to DARPA-BAA-10-37 must be submitted through T-FIMS. See https://www.tfims.darpa.mil/baa/ for more information on how to request an account, upload proposals, and use the T-FIMS tool. Because proposers using T-FIMS may encounter heavy traffic on the web server, and T-FIMS requires a registration and certificate installation for all proposers, it is strongly suggested that proposers not wait until the initial due date the proposal is due to create an account in T-FIMS and submit the proposal. All proposers using T-FIMS must also encrypt the proposal, per the instructions below.

All proposals submitted electronically through T-FIMS must be encrypted using Winzip or PKZip with 256-bit AES encryption. Only one zipped/encrypted file will be accepted per proposal. Proposals which are not zipped/encrypted will be rejected by DARPA. An encryption password form must be completed and emailed to DARPA-BAA-10-37@darpa.mil at the time of proposal submission. See https://www.tfims.darpa.mil/baa/ for the encryption password form.

Note the word "PASSWORD" must appear in the subject line of the above email and there are minimum security requirements for establishing the encryption password. Failure to provide the encryption password may result in the proposal not being evaluated. For further information and instructions on how to zip and encrypt proposal files, see https://www.tfims.darpa.mil/baa/.

3. Proposal Preparation and Format

The proposal shall be delivered in two volumes, Volume 1 (technical proposal) and Volume 2 (cost proposal). Proposals not meeting the format described in this BAA may be rejected without review.

The technical proposal shall include the following sections, each starting on a new page (where a "page" is 8-1/2 by 11 inches with type not smaller than 12 point, charts may use 10 pt font, margins not smaller than 1 inch, and line spacing not smaller than single-spaced). All submissions must be in English. Individual elements of the proposal shall not exceed the total of the maximum page lengths for each section as shown in braces { } below.

Volume 1 – Technical and Management Proposal

Proposal Section 1 - Administrative

1.1 Cover Sheet

The cover sheet should contain the following information:

- BAA number;
- Proposal title;
- Technical area;
- Lead organization submitting the proposal;
- Technical point of contact, including: name, telephone number, electronic mail address, fax (if available), and mailing address;
- Administrative point of contact, including: name, telephone number, electronic mail address, fax (if available), and mailing address;
- Total funds requested from DARPA. Summary of the costs of the proposed research, including total base cost, estimates of base cost in each year of the effort, estimates of itemized options in each year of the effort, and cost sharing if relevant;
- Contractor's reference number (if any); and
- Contractor's type of business, selected from among the following categories:
  - WOMEN-OWNED LARGE BUSINESS,
  - OTHER LARGE BUSINESS,
  - SMALL DISADVANTAGED BUSINESS [Identify ethnic group from among the following: Asian-Indian American, Asian-Pacific American, Black American,

Hispanic American, Native American, or Other],
  - WOMEN-OWNED SMALL BUSINESS,
  - OTHER SMALL BUSINESS,
  - HBCU,
  - MI,
  - OTHER EDUCATIONAL,
  - OTHER NONPROFIT, or
  - FOREIGN CONCERN/ENTITY.
- Other team members (if applicable) and type of business for each.

1.2 Official Transmittal Letter

1.3 Table of Contents {No page limit}

Proposal Section 2 - Technical Details

2.1 PowerPoint Summary Chart {1 chart}
Provide a one slide summary of the proposal in PowerPoint that effectively and succinctly conveys the main objective, key innovations, expected impact, and other unique aspects of the proposal.

2.2 Innovative Claims for the Proposed Research {5 pages}
This page is the centerpiece of the proposal and should succinctly describe the unique proposed approach and contributions. This section may also *briefly* address the following topics:

a. Problem Description - Provide a concise description of the problem areas addressed. Make this specific to your approach.
b. Research Goals - Identify specific research goals. Goals should address the technical challenges of the effort.
c. Expected Impact - Describe the expected impact of your research.

2.3 Proposal Roadmap {5 pages}
The roadmap provides a top-level view of the content and structure of the proposal. It contains a synopsis for each of the roadmap areas defined below, which should be elaborated elsewhere. It is important to make the synopses as explicit and informative as possible. The roadmap must also cross-reference the proposal page number(s) where each area is elaborated. The required roadmap areas are:

a. Main goals of the proposed research.
b. Tangible benefits to end users (i.e., benefits of the capabilities afforded if the proposed technology is successful).
c. Critical technical barriers (i.e., technical limitations that have, in the past, prevented achieving the proposed results).
d. Main elements of the proposed technical approach.
e. Basis of confidence (i.e. rationale that builds confidence that the proposed approach will overcome the technical barriers).
f. Nature and description of end results to be delivered to DARPA. In what form will results be developed and delivered to DARPA and the scientific community? Note that

DARPA encourages experiments, simulations, specifications, proofs, etc. to be documented and published to promote progress in the field. Proposers should specify both final and intermediate products.

g. Cost and schedule of the proposed effort.

2.4 Technical Approach {35 pages}

Provide a detailed description of the technical approach. Teams may choose to allocate the pages among the program phases unequally; however, separate sections are required for each phase. This section will elaborate on many of the topics identified in the proposal roadmap and will serve as the primary expression of the proposers' scientific and technical ideas.

2.5 Statement of Work (SOW) {5 pages}

In plain English, clearly define the technical tasks/subtasks to be performed, their durations, and dependencies among them. For each task/subtask, provide:

- A general description of the objective (for each defined task/activity);
- A detailed description of the approach to be taken to accomplish each defined task/activity);
- Identification of the primary organization responsible for task execution (prime, sub, team member, by name, etc.);
- The completion criteria for each task/activity - a product, event or milestone that defines its completion.
- Define all deliverables (reports, data, software, hardware, prototypes, etc.) to be provided to the Government in support of the proposed research tasks/activities. Include expected delivery date for each deliverable.
- Cost, schedule and measurable milestones for the proposed research, including estimates of cost for each major task in each year of the effort delineated by the prime and major subcontractors, total cost and company cost share, if applicable. (Note: Measurable milestones should capture key development points in tasks and should be clearly articulated and defined in time relative to start of effort.)

Note: The SOW should be developed so that each phase of the program is separately defined. Do not include any proprietary information in the SOW.

2.6 Intellectual Property {No page limit}

Per section VIII - Other Information, proposers responding to this BAA must submit a separate list of all technical data or computer software that will be furnished to the Government with other than unlimited rights. The Government will assume unlimited rights if proposers fail to identify any intellectual property restrictions in their proposals. Include in this section all proprietary claims to results, prototypes, deliverables or systems supporting and/or necessary for the use of the research, results, prototypes and/or deliverables. If no restrictions are intended, then the proposer should state "NONE".

UHPC IP Lineage Document - This document must specify all IP that is utilized in a team's UHPC System Design initially including all UHPC background IP and how it will be utilized. The document will provide a clear description of the IP, the ownership, licensees and rights associated with the IP.

Note: Please also refer to page 27 of this BAA document regarding IP.

2.7 Management Plan {6 pages}

Describe formal teaming agreements that are required to execute this program, a brief synopsis of all key personnel, and a clearly defined organization chart for the program team (prime contractor and subcontractors, if any). Provide an argument that the team size and composition are both necessary and sufficient to meet the program objectives. Provide detailed task descriptions, costs, and interdependencies for each individual effort and/or subcontractor. To the extent that graduate students and postdocs are involved in individual efforts, describe their role and contribution. Information in this section must cover the following information:

a. Programmatic relationship of team members;
b. Unique capabilities of team members;
c. Task responsibilities of team members;
d. Teaming strategy among the team members;
e. Key personnel along with the amount of effort to be expended by each person during each year; and
f. Government role in project, if any.

2.8 Schedule and Milestones

This section should include:

a. {1 page} Schedule Graphic - Provide a graphic representation of project schedule including detail down to the individual effort level. This should include but not be limited to, a multi-phase development plan, which demonstrates a clear understanding of the proposed research; and a plan for periodic and increasingly robust tests over the project life that will show applicability to the overall program concept. Show all project milestones. Use “x months after contract award” designations for all dates.
b. {2 pages} Detailed Task Descriptions - Provide detailed task descriptions for each discrete work effort and/or subcontractor in schedule graphic.
c. {5 pages} Project Management and Interaction Plan - Describe the project management and interaction plans for the proposed work. If proposal includes subcontractors that are geographically distributed, clearly specify working/meeting models. Items to include in this category include software/code repositories, physical and virtual meeting plans, and online communication systems that may be used.

2.9 Personnel, Qualifications, and Commitments {2 pages per key personnel}

List key personnel, showing a concise summary of their qualifications. Provide a description of any previous accomplishments or similar efforts completed/ongoing in this or closely related research area, including identification of other Government sponsors, if any.

Indicate the level of effort in terms of hours to be expended by each person during each contract year and other (current and proposed) major sources of support for them and/or commitments of their efforts. DARPA expects all key personnel associated with a proposal to make substantial time commitment to the proposed activity and the proposal will be evaluated accordingly. It is DARPA’s intention to put key personnel clauses into the contracts, so proposers should not bid personnel whom they do not intend to execute the contract.

Include a table of key individual time commitments as follows:

Key Individual	Project	Pending/Current	2010	2011	2012
Jane Doe	Program Name	Proposed	ZZZ hours	UUU hours	WWW hours
	Project 1	Current	n/a	n/a	n/a
	Project 2	Pending	100 hours	n/a	n/a
John Deer	Program Name	Proposed			

2.10 Organizational Conflict of Interest Affirmations and Disclosure {No page limit}
Per the instructions in section III.A.1 above, if the proposer or any proposed sub IS providing SETA support, as described, to any DARPA technical office(s) through an active contract or subcontract (regardless of which DARPA technical office is being supported), they must provide documentation: 1) stating which office(s) the proposer, sub and/or individual supports, 2) identify the prime contract numbers AND 3) include a description of the action the proposer has taken or proposes to take to avoid, neutralize, or mitigate the conflict.

If the proposer or any proposed sub IS NOT currently providing SETA support as described, then the proposer should simply state "NONE."

Proposals that fail to fully disclose potential conflicts of interests or do not have acceptable plans to mitigate identified conflicts will be rejected without technical evaluation and withdrawn from further consideration for award.

2.11 Human Use {No page limit}
For all proposed research that will involve human subjects in the first year or phase of the project, the institution must provide evidence of or a plan for review by an Institutional Review Board (IRB) upon final proposal submission to DARPA. For further information on this subject, see section VI.B.4 below. If human use is not a factor in a proposal, then the proposer should state "NONE."

2.12 Animal Use {No page limit}
For submissions containing animal use, proposals must briefly describe plans for Institutional Animal Care and Use Committee (IACUC) review and approval. For further information on this subject, see Section VI.B.5 below. If animal use is not a factor in a proposal, then the proposer should state "NONE."

2.13 Statement of Unique Capability Provided by Government or Government-funded Team Member {No page limit}
Per section III.A. - Eligible Applicants, proposals which include Government or Government-funded entities (i.e., FFRDC's, National laboratories, etc.) as prime, sub or team member, shall

provide a statement which clearly demonstrates the work being provided by the Government or Government-funded entity team member is not otherwise available from the private sector. If none of the team members belongs to a Government or Government-funded entity, then the proposer should state "Not Applicable."

2.14 Government or Government-funded Team Member Eligibility {No page limit}
Per section III.A. - Eligible Applicants, proposals which include Government or Government-funded entities (i.e., FFRDC's, National laboratories, etc.) as prime, sub or team member shall provide documentation citing the specific authority which establishes they are eligible to propose to Government solicitations: 1) statutory authority; 2) contractual authority; 3) supporting regulatory guidance; AND 4) evidence of agency approval. If no such entities are involved, then the proposer should state "None."

2.15 Facilities {4 pages}
Provide a description of the facilities that would be used for the proposed effort. If any portion of the research is predicated upon the use of Government Owned Resources of any type, the proposer shall specifically identify the property or other resource required, the date the property or resource is required, the duration of the requirement, the source from which the resource is required, if known, and the impact on the research if the resource cannot be provided. If no Government Furnished Property is required for conduct of the proposed research, the proposal shall so state.

<u>Volume 2 – Cost Proposal</u>

Cover Sheet

The cover sheet should contain the following information:

- BAA number;
- Technical area;
- Lead Organization Submitting proposal;
- Type of business, selected among the following categories: "LARGE BUSINESS", "SMALL DISADVANTAGED BUSINESS", "OTHER SMALL BUSINESS", "HBCU", "MI", "OTHER EDUCATIONAL", OR "OTHER NONPROFIT";
- Contractor's reference number (if any);
- Other team members (if applicable) and type of business for each;
- Proposal title;
- Technical point of contact to include: salutation, last name, first name, street address, city, state, zip code, telephone, fax (if available), electronic mail (if available);
- Administrative point of contact to include: salutation, last name, first name, street address, city, state, zip code, telephone, fax (if available), and electronic mail (if available);
- Award instrument requested: cost-plus-fixed-free (CPFF), cost-contract—no fee, cost sharing contract – no fee, or other type of procurement contract (*specify*), or other transaction;
- Place(s) and period(s) of performance;
- Total proposed cost separated by basic award and option(s) (if any);

- Name, address, and telephone number of the proposer's cognizant Defense Contract Management Agency (DCMA) administration office (*if known)*;
- Name, address, and telephone number of the proposer's cognizant Defense Contract Audit Agency (DCAA) audit office (*if known*);
- Date proposal was prepared;
- DUNS number;
- TIN number;
- Cage code;
- Subcontractor information; and
- Proposal validity period (minimum 180 days).

Cost Summaries {5 pages}
Provide a top-level total cost summary for the entire program broken down by phases. Show each major task and subtask by month and delineate prime and major subcontractor efforts. Proposers should format their proposals for Phase 1, with Phase 2 priced as an option. Phase III should be proposed as a Rough Order of Magnitude (ROM).

Detailed Cost Breakdown
For purposes of building your cost proposal, assume an estimated start date of 1 June 2010. Proposers should format their cost proposals as follows for Phase I and Phase II. Phase II should be proposed as a priced Option. Phase III should be proposed as a Rough Order of Magnitude (ROM).

Provide: (1) total program cost broken down by major cost items (direct labor, including labor categories; subcontracts; materials; other direct costs, overhead charges, etc.) and further broken down by task and phase; (2) major program tasks by fiscal year; (3) an itemization of major subcontracts and equipment purchases; (4) an itemization of any information technology (IT) purchase[18]; (5) a summary of projected funding requirements by month; and (6) the source, nature, and amount of any industry cost-sharing; (7) identification of pricing assumptions of which may require incorporation into the resulting award instrument (e.g., use of Government Furnished Property/Facilities/Information, access to Government Subject Matter Expert/s, etc.)

[18] IT is defined as "any equipment, or interconnected system(s) or subsystem(s) of equipment that is used in the automatic acquisition, storage, manipulation, management, movement, control, display, switching, interchange, transmission, or reception of data or information by the agency. (a) For purposes of this definition, equipment is used by an agency if the equipment is used by the agency directly or is used by a contractor under a contract with the agency which – (1) Requires the use of such equipment; or (2) Requires the use, to a significant extent, or such equipment in the performance of a service or the furnishing of a product. (b) The term "information technology" includes computers, ancillary, software, firmware and similar procedures, services (including support services), and related resources. (c) The term "information technology" does not include – (1) Any equipment that is acquired by a contractor incidental to a contract; or (2) Any equipment that contains imbedded information technology that is used as an integral part of the product, but the principal function of which is not the acquisition, storage, manipulation, management, movement, control, display, switching, interchange, transmission, or reception of data or information. For example, HVAC (heating, ventilation, and air conditioning) equipment such as thermostats or temperature control devices, and medical equipment where information technology is integral to its operation, are not information technology."

and 8) provide appropriate cost or price analyses of subcontractor proposals, IAW FAR 15.404-3, to establish the reasonableness of proposed subcontract prices.

The prime contractor is responsible for compiling and providing all subcontractor proposals for the Procuring Contracting Officer (PCO) with the submission of this proposal. Subcontractor proposals should include Interdivisional Work Transfer Agreements (ITWA) or similar arrangements. Where the effort consists of multiple portions, which could reasonably be partitioned for purposes of funding, these should be identified as options with separate cost estimates for each. NOTE: For IT and equipment purchases, include a letter stating why the proposer cannot provide the requested resources from its own funding.

Provide supporting cost and pricing information in sufficient detail to substantiate the summary cost estimates above. Include a description of the method used to estimate costs and supporting documentation. Note: "Cost or pricing data" as defined in FAR Subpart 15.4 shall be required if the proposer is seeking a procurement contract award of $650,000 or greater unless the proposer requests an exception from the requirement to submit cost or pricing data. "Cost or pricing data" are not required if the proposer proposes an award instrument other than a procurement contract (e.g., other transaction.) All proprietary subcontractor proposal documentation, prepared at the same level of detail as that required of the prime, shall be made immediately available to the Government, upon request, under separate cover (i.e., mail, electronic/email, etc.), either by the proposer or by the subcontractor organization.

For information on 845 Other Transaction Authority for Prototypes (OTA) agreements, refer to http://www.darpa.mil/cmo/other_trans.html. All proposers requesting an 845 Other Transaction Authority for Prototypes (OTA) agreement must include a detailed list of milestones. Each such milestone must include the following: milestone description, completion criteria, due date, payment/funding schedule (to include, if cost share is proposed, contractor and Government share amounts). It is noted that, at a minimum, such milestones should relate directly to accomplishment of program technical metrics as defined in the BAA and/or the proposer's proposal. Agreement type, fixed price or expenditure based, will be subject to negotiation by the Agreements Officer; however, it is noted that the Government prefers use of fixed price milestones with a payment/funding schedule to the maximum extent possible. Do not include proprietary data. If the proposer requests award of an 845 OTA agreement as a nontraditional defense contractor, as so defined in the OSD guide entitled "Other Transactions (OT) Guide For Prototype Projects" dated January 2001 (as amended) (http://www.acq.osd.mil/dpap/Docs/otguide.doc), information must be included in the cost proposal to support the claim. Additionally, if the proposer requests award of an 845 OTA agreement, without the required one-third (1/3) cost share, information must be included in the cost proposal supporting that there is at least one non-traditional defense contractor participating to a significant extent in the proposed prototype project.

C. Submission Dates and Times

The full proposal must be submitted per the instructions in Section IV.B. - Content and Form of Application Submission above by 1200 noon (ET), 16 April 2010 (initial closing), in order to be considered during the initial evaluation phase. While DARPA-BAA-10-37 will remain open until 1200 noon (ET), 30 August 2010 (final closing date/BAA expiration), proposers are warned that the likelihood of funding is greatly reduced for proposals submitted after the initial closing date.

DARPA will acknowledge receipt of complete submissions via email and assign control numbers that should be used in all further correspondence regarding proposals.

Failure to comply with the submission procedures may result in the submission not being evaluated.

D. Intergovernmental Review - N/A

E. Funding Restrictions

The Defense Appropriations Act caps indirect cost rates at 35% of the total cost of the award for any procurement contract, grant or agreement using 6.1 Basic Research Funding. The cost limitations do not flow down to subcontractors. Total costs include all bottom line costs. Indirect costs are defined as follows:

- For Educational Institutions subject to the cost principles in 2 CFR part 220, indirect costs are all costs of a prime award that are Facilities and Administration costs.

- For State, Local, and Indian Tribal Governments subject to 2 CFR part 225, Non-Profit Organizations subject to 2 CFR part 230 and all other organizations subject to 48 CFR part 32 Federal Acquisition Regulation, indirect cost are any cost not directly identified with a single final cost objective (i.e. costs identified with two or more final cost objectives or with at least one intermediate cost objective).

DARPA currently anticipates using 6.2 funding for this program.

F. Other Submission Requirements

Proposals MUST NOT be submitted to DARPA via email or fax (see Submission instructions above in section IV.B.).

V. APPLICATION REVIEW INFORMATION

A. Evaluation Criteria

Evaluation of proposals will be accomplished through a scientific review of each proposal using the following criteria. While these criteria are listed in descending order of relative importance, it should be noted that the combination of all non-cost evaluation factors is significantly more important than cost.

1. **Overall Scientific and Technical Merit**

The proposer's proposal will be evaluated on the long-term effects of the proposed research including the impact on technology, whether there is sufficient technical payoff to warrant any risk and the proposer's ability to meet program metrics. In addition, the proposed technical approach will be evaluated for feasibility, achievability, completeness and whether it is supported by a proposed technical team that has the expertise and experience to accomplish the proposed tasks. The expertise and experience of the proposer's proposed technical team will be evaluated based upon the qualifications of the key personnel proposed for the effort and their previous accomplishments on similar efforts.

The proposer's proposal must describe how they will utilize open innovation throughout the proposed research and design process. This is a critical element throughout the UHPC program and will be heavily considered in the scientific review process.

2. **Potential Contribution and Relevance to the DARPA Mission**

The potential contributions of the proposed effort with relevance to the national technology base will be evaluated. Specifically, DARPA's mission is to maintain the technological superiority of the U.S. military and prevent technological surprise from harming our national security by sponsoring revolutionary, high-payoff research that bridges the gap between fundamental discoveries and their application.

3. **Plans and Capability to Accomplish Technology Transition**

The evaluation will take into consideration the extent to which intellectual property (IP) rights limitations creates a barrier to technology transition. The technology utilized in the proposed design must eventually be viable in the commercial market space.

4. **Cost Realism**

The objective of this criterion is to establish that the proposed costs are realistic for the proposed approach, as well as to determine the proposer's practical understanding of the effort. The proposal will be reviewed to determine if the costs proposed are based on realistic assumptions, reflect a sufficient understanding of the technical goals and objectives of the BAA, and are consistent with the proposer's technical approach (to include the proposed Statement of Work). At a minimum, this will involve review, at the prime and subcontract level, of the number and types of labor-hours proposed (quantity and mix) per task as well as the types and quantity of materials, equipment and fabrication costs, travel and other various elements proposed.

NOTE: PROPOSERS ARE CAUTIONED THAT PROPOSALS MAY BE REJECTED IF SUBMITTAL INSTRUCTIONS ARE NOT FOLLOWED.

B. Review and Recommendation Process

It is the policy of DARPA to ensure impartial, equitable, comprehensive proposal evaluations and to select the source (or sources) whose offer meets the Government's technical, policy, and programmatic goals. Pursuant to FAR 35.016, the primary basis for selecting proposals for acceptance shall be technical, importance to agency programs, and fund availability. In order to provide the desired evaluation, qualified Government personnel will conduct reviews and (if necessary) convene panels of experts in the appropriate areas.

Each proposal will be evaluated on the merit and relevance of the specific proposal as it relates to the office rather than against other proposals for research in the same general area, since no common work statement exists. DARPA's intent is to review proposals as soon as possible after they arrive; however, proposals may be reviewed periodically for administrative reasons. For evaluation purposes, a proposal is the document described above in section IV.B. - Content and Form of Application Submission. Other supporting or background materials submitted with the proposal will be considered for the reviewer's convenience only and not considered as part of the proposal.

Award(s) will be made to proposers whose proposals are determined to be the most advantageous to the Government, all factors considered, including the potential contributions of the proposed work to the overall research program and the availability of funding for the effort. Award(s) may be made to any proposer whose proposal is determined selectable regardless of its overall rating.

Restrictive notices notwithstanding, proposers are advised that employees of commercial firms under contract to the Government may be used by DARPA to administratively process proposals, monitor contract performance, or perform other administrative duties requiring access to other contractors' proprietary information. These support contracts include nondisclosure agreements prohibiting their contractor employees from disclosing any information submitted by other contractors or using such information for any purpose other than that for which it was furnished. By submission of its proposal, each proposer agrees that proposal information may be disclosed to those non-Government personnel for the limited purposes stated above. In addition, these support contractors are prohibited from competition in DARPA technical research. Subject to the restrictions set forth in FAR 37.203(d), input on technical aspects of the proposals may be solicited by DARPA from non-Government consultants/experts who are strictly bound by the appropriate non-disclosure requirements.

It is the policy of DARPA to treat all proposals as competitive information and to disclose their contents only for the purpose of evaluation. No proposals will be returned. Upon completion of the scientific review process, the original electronic uploaded file of each proposal received will be retained at DARPA for an indefinite period of time.

VI. AWARD ADMINISTRATION INFORMATION

A. Award Notices

As soon as the evaluation of a proposal is complete, the proposer will be notified that 1) the proposal has been selected for funding pending contract negotiations, or, 2) the proposal has not been selected. These official notifications will be sent via US mail to the Technical POC identified on the proposal coversheet.

B. Administrative and National Policy Requirements

1. Meeting and Travel Requirements (Please refer to page 25 of this document regarding Program Meetings)

2. Human Use

All research involving human subjects, to include use of human biological specimens and human data, selected for funding must comply with the federal regulations for human subject protection. Further, research involving human subjects that is conducted or supported by the DoD must comply with 32 CFR 219, *Protection of Human Subjects* (http://www.dtic.mil/biosys/downloads/32cfr219.pdf), and DoD Directive 3216.02, *Protection of Human Subjects and Adherence to Ethical Standards in DoD-Supported Research* (http://www.dtic.mil/whs/directives/corres/html2/d32162x.htm).

Institutions awarded funding for research involving human subjects must provide documentation of a current Assurance of Compliance with Federal regulations for human subject protection, for example a Department of Health and Human Services, Office of Human Research Protection Federal Wide Assurance (http://www.hhs.gov/ohrp). All institutions engaged in human subject research, to include subcontractors, must also have a valid Assurance. In addition, personnel involved in human subjects research must provide documentation of completing appropriate training for the protection of human subjects.

For all proposed research that will involve human subjects in the first year or phase of the project, the institution must provide evidence of or a plan for review by an Institutional Review Board (IRB) upon final proposal submission to DARPA. The IRB conducting the review must be the IRB identified on the institution's Assurance. The protocol, separate from the proposal, must include a detailed description of the research plan, study population, risks and benefits of study participation, recruitment and consent process, data collection, and data analysis. Consult the designated IRB for guidance on writing the protocol. The informed consent document must comply with federal regulations (32 CFR 219.116). A valid Assurance, along with evidence of appropriate training for all investigators, should accompany the protocol for review by the IRB.

In addition to a local IRB approval, a headquarters-level human subjects regulatory review and approval is required for all research conducted or supported by the DoD. The Army, Navy, or Air Force office responsible for managing the award can provide guidance and information about their component's headquarters-level review process. Note that confirmation of a current Assurance and appropriate human subjects protection training is required before headquarters-level approval can be issued.

The amount of time required to complete the IRB review/approval process may vary depending on the complexity of the research and/or the level of risk to study participants. Ample time should be allotted to complete the approval process. The IRB approval process can last for one to three months, followed by a DoD review that can last for three to six months. No DoD/DARPA funding can be used toward human subjects research until ALL approvals are granted.

3. Animal Use

Any Recipient performing research, experimentation, or testing involving the use of animals shall comply with the rules on animal acquisition, transport, care, handling, and use in: (i) 9 CFR parts 1-4, Department of Agriculture rules that implement the Laboratory Animal Welfare Act of 1966, as amended, (7 U.S.C. 2131-2159); (ii) the guidelines described in National Institutes of Health Publication No. 86-23, "Guide for the Care and Use of Laboratory Animals"; (iii) DoD Directive 3216.01, "Use of Laboratory Animals in DoD Program."

For submissions containing animal use, proposals should briefly describe plans for Institutional Animal Care and Use Committee (IACUC) review and approval. Animal studies in the program will be expected to comply with the PHS Policy on Humane Care and Use of Laboratory Animals, available at http://grants.nih.gov/grants/olaw/olaw.htm.

All Recipients must receive approval by a DoD certified veterinarian, in addition to an IACUC approval. No animal studies may be conducted using DoD/DARPA funding until the USAMRMC Animal Care and Use Review Office (ACURO) or other appropriate DoD veterinary office(s) grant approval. As a part of this secondary review process, the Recipient will be required to complete and submit an ACURO Animal Use Appendix, which may be found at https://mrmc.amedd.army.mil/AnimalAppendix.asp

4. Publication Approval

It is the policy of the Department of Defense that the publication of products of fundamental research will remain unrestricted to the maximum extent possible. The definition of Contracted Fundamental Research is:

"Contracted Fundamental Research includes [research performed under] grants and contracts that are (a) funded by budget category 6.1 (Basic Research), whether performed by universities or industry or (b) funded by budget category 6.2 (Applied Research) and performed on-campus at a university. The research shall not be considered fundamental in those rare and exceptional circumstances where the applied research effort presents a high likelihood of disclosing performance characteristics of military systems or manufacturing technologies that are unique and critical to defense, and where agreement on restrictions have been recorded in the contract or grant." Such research is referred to by DARPA as "Restricted Research."

Pursuant to DoD policy, research performed under grants and contracts that are (a) funded by budget category 6.2 (Applied Research) and NOT performed on-campus at a university or (b) funded by budget category 6.3 (Advanced Research) does not meet the definition of fundamental research. Publication restrictions will be placed on all such research.

The performance of research resulting from the BAA could be fundamental research for universities and non-profit organizations.

Proposers are advised if they propose grants or cooperative agreements, DARPA may elect to employ other award instruments. DARPA will make this election if it determines that the research resulting from the proposed program will present a high likelihood of disclosing performance characteristics of military systems or manufacturing technologies that are unique and critical to defense. Any award resulting from such a determination will include a requirement for DARPA permission before publishing any information or results on the program and will be considered Restricted Research.

For certain research projects, it may be possible that although the research being performed by the Prime Contractor is Restricted Research, a subcontractor may be conducting Contracted Fundamental Research. In those cases, it is the Prime Contractor's responsibility to explain in their proposal why its subcontractor's effort is Contracted Fundamental Research.

The following same or similar provision will be incorporated into any resultant Restricted Research or Non-Fundamental Research procurement contract or other transaction:

There shall be no dissemination or publication, except within and between the Contractor and any subcontractors, of information developed under this contract or contained in the reports to be furnished pursuant to this contract without prior written approval of the DARPA Public Release Center (PRC). All technical reports will be given proper review by appropriate authority to determine which Distribution Statement is to be applied prior to the initial distribution of these reports by the Contractor. With regard to subcontractor proposals for Contracted Fundamental Research, papers resulting from unclassified contracted fundamental research are exempt from prepublication controls and this review requirement, pursuant to DoD Instruction 5230.27 dated October 6, 1987.

> When submitting material for written approval for open publication, the Contractor/Awardee must submit a request for public release to the DARPA PRC and include the following information: 1) Document Information: document title, document author, short plain-language description of technology discussed in the material (approx. 30 words), number of pages (or minutes of video) and document type (briefing, report, abstract, article, or paper); 2) Event Information: event type (conference, principle investigator meeting, article or paper), event date, desired date for DARPA's approval; 3) DARPA Sponsor: DARPA Program Manager, DARPA office, and contract number; and 4) Contractor/Awardee's Information: POC name, e-mail and phone. Allow four weeks for processing; due dates under four weeks require a justification. Unusual electronic file formats may require additional processing time. Requests can be sent either via e-mail to public_release_center@darpa.mil or via 3701 North Fairfax Drive, Arlington VA 22203-1714, telephone (571) 218-4235. Refer to www.darpa.mil/tio for information about DARPA's public release process.

5. Export Control

Should this project develop beyond fundamental research (basic and applied research ordinarily published and shared broadly within the scientific community) with military or dual-use applications the following apply:

- The Contractor shall comply with all U. S. export control laws and regulations, including the International Traffic in Arms Regulations (ITAR), 22 CFR Parts 120 through 130, and the Export Administration Regulations (EAR), 15 CFR Parts 730 through 799, in the performance of the contract or agreement. In the absence of available license exemptions/exceptions, the Contractor shall be responsible for obtaining the appropriate licenses or other approvals, if required, for exports (including deemed exports) of hardware, technical data, and software, or for the provision of technical assistance.

- The Contractor shall be responsible for obtaining export licenses, if required, before utilizing foreign persons in the performance of this contract, including instances where the work is to be performed on-site at any Government installation (whether in or outside the United States), where the foreign person will have access to export-controlled technologies, including data or software.
- The Contractor shall be responsible for all regulatory record keeping requirements associated with the use of licenses and license exemptions/exceptions.
- The Contractor shall be responsible for ensuring that the provisions of this clause apply to its subcontractors**.**

6. Subcontracting

Pursuant to Section 8(d) of the Small Business Act (15 U.S.C. 637(d)), it is the policy of the Government to enable small business and small disadvantaged business concerns to be considered fairly as subcontractors to contractors performing work or rendering services as prime contractors or subcontractors under Government contracts, and to assure that prime contractors and subcontractors carry out this policy. Each proposer who submits a contract proposal and includes subcontractors is required to submit a subcontracting plan in accordance with FAR 19.702(a) (1) and (2) should do so with their proposal. The plan format is outlined in FAR 19.704.

7. Central Contractor Registration (CCR)

Proposers selected, but not already registered in the Central Contractor Registry (CCR) will be required to register in CCR prior to any award under this BAA. Information on CCR registration is available at http://www.ccr.gov

8. On-line Representations and Certifications (ORCA)

In accordance with FAR 4.1201, prospective proposers shall complete electronic annual representations and certifications at http://orca.bpn.gov.

9. Wide Area Work Flow (WAWF)

Unless using another approved electronic invoicing system, performers will be required to submit invoices for payment directly via the Internet/WAWF at http://wawf.eb.mil. Registration to WAWF will be required prior to any award under this BAA.

10. Electronic and Information Technology

All electronic and information technology acquired through this solicitation must satisfy the accessibility requirements of Section 508 of the Rehabilitation Act (29 U.S.C. 794d) and FAR Subpart 39.2. Each proposer who submits a proposal involving the creation or inclusion of electronic and information technology must ensure that Federal employees with disabilities will have access to and use of information that is comparable to the access and use by Federal employees who are not individuals with disabilities and members of the public with disabilities seeking information or services from DARPA will have access to and use of information and data that is comparable to the access and use of information and data by members of the public who are not individuals with disabilities.

11. Employment Eligibility Verification

As per FAR 22.1802, recipients of FAR-based procurement contracts must enroll as Federal Contractors in E-verify and use E-Verify to verify employment eligibility of all employees assigned to the award. All resultant contracts from this solicitation will include FAR 52.222-54, "Employment Eligibility Verification." This clause will not be included in grants, cooperative agreements, or Other Transactions.

C. Reporting

The number and types of reports will be specified in the award document, but will include as a minimum monthly financial status reports and an annual project summary. In addition, each performing contractor (including subs) on each team will be expected to provide monthly status reports to the Program Manager. Reports and briefing material will also be required as appropriate to document progress in accomplishing program metrics. These shall be prepared and submitted in accordance with the procedures contained in the award document. A Final Report that summarizes the project and tasks will be required at the conclusion of the performance period for the award, notwithstanding the fact that the research may be continued under a follow-on vehicle. There may also be additional reporting requirements for Other Transactions.

1. T-FIMS

The above reports may be electronically submitted by each awardee under this BAA via the DARPA Technical – Financial Information Management System (T-FIMS). If applicable, the T-FIMS URL and instructions will be furnished by the contracting agent prior to award.

2. I-Edison

All required reporting shall be accomplished, as applicable, using the i-Edison.gov reporting website at http://s-edison.info.nih.gov/iEdison.

VII. AGENCY CONTACTS

DARPA will use electronic mail for all technical and administrative correspondence regarding this BAA, with the exception of selected/not-selected notifications.

Administrative, technical or contractual questions should be sent via e-mail to DARPA-BAA-10-37@darpa.mil. If e-mail is not available, please fax questions to (703) 465-8096, Attention: Ubiquitous High Performance Computing Solicitation. All requests must include the name, email address, and phone number of a point of contact.

Solicitation Web Site: http://www.darpa.mil/tcto_solicitations.html

VIII. OTHER INFORMATION

1. Intellectual Property

a. Procurement Contract Proposers

i. Noncommercial Items (Technical Data and Computer Software)

Proposers responding to this BAA requesting a procurement contract to be issued under the FAR/DFARS shall identify all noncommercial technical data and noncommercial computer software that it plans to generate, develop, and/or deliver under any proposed award instrument in which the Government will acquire less than unlimited rights, and to assert specific restrictions on those deliverables. Proposers shall follow the format under DFARS 252.227-7017 for this stated purpose. In the event that proposers do not submit the list, the Government will assume that it automatically has “unlimited rights” to all noncommercial technical data and noncommercial computer software generated, developed, and/or delivered under any award instrument, unless it is substantiated that development of the noncommercial technical data and noncommercial computer software occurred with mixed funding. If mixed funding is anticipated in the development of noncommercial technical data and noncommercial computer software generated, developed, and/or delivered under any award instrument, then proposers should identify the data and software in question, as subject to Government Purpose Rights (GPR). In accordance with DFARS 252.227-7013 Rights in Technical Data - Noncommercial Items, and DFARS 252.227-7014 Rights in Noncommercial Computer Software and Noncommercial Computer Software Documentation, the Government will automatically assume that any such GPR restriction is limited to a period of five (5) years in accordance with the applicable DFARS clauses, at which time the Government will acquire “unlimited rights” unless the parties agree otherwise. Proposers are admonished that the Government may use the list during the scientific review process to evaluate the impact of any identified restrictions and may request additional information from the proposer, as may be necessary, to evaluate the proposer’s assertions. If no restrictions are intended, then the proposer should state “NONE.”

A sample list for complying with this request is as follows:

NONCOMMERCIAL			
Technical Data Computer Software To be Furnished With Restrictions	Basis for Assertion	Asserted Rights Category	Name of Person Asserting Restrictions
(LIST)	(LIST)	(LIST)	(LIST)

ii. Commercial Items (Technical Data and Computer Software)

Proposers responding to this BAA requesting a procurement contract to be issued under the FAR/DFARS shall identify all commercial technical data and commercial computer software (including open source software) that may be embedded in, or that may create linkages affecting distribution rights to, any noncommercial deliverables contemplated under the research effort, along with any applicable restrictions on the Government’s use of such commercial technical data and/or commercial computer software. In the event that proposers do not submit the list, the

Government will assume that there are no restrictions on the Government's use of such commercial items. The Government may use the list during the scientific review process to evaluate the impact of any identified restrictions and may request additional information from the proposer, as may be necessary, to evaluate the proposer's assertions. If no restrictions are intended, then the proposer should state "NONE."

A sample list for complying with this request is as follows:

COMMERCIAL			
Technical Data Computer Software To be Furnished With Restrictions	Basis for Assertion	Asserted Rights Category	Name of Person Asserting Restrictions
(LIST)	(LIST)	(LIST)	(LIST)

b. Non-Procurement Contract Proposers – Noncommercial and Commercial Items (Technical Data and Computer Software)

Proposers responding to this BAA requesting a Procurement Contract or Other Transaction shall follow the applicable rules and regulations governing these various award instruments, but in all cases should appropriately identify any potential restrictions on the Government's use of any Intellectual Property contemplated under those award instruments in question. This includes both Noncommercial Items and Commercial Items. Although not required, proposers may use a format similar to that described above. The Government may use the list during the scientific review process to evaluate the impact of any identified restrictions, and may request additional information from the proposer, as may be necessary, to evaluate the proposer's assertions. If no restrictions are intended, then the proposer should state "NONE."

c. All Proposers – Patents

Include documentation proving your ownership of or possession of appropriate licensing rights to all patented inventions (or inventions for which a patent application has been filed) that will be utilized under your proposal for the DARPA program. If a patent application has been filed for an invention that your proposal utilizes, but the application has not yet been made publicly available and contains proprietary information, you may provide only the patent number, inventor name(s), assignee names (if any), filing date, filing date of any related provisional application, and a summary of the patent title, together with either: 1) a representation that you own the invention, or 2) proof of possession of appropriate licensing rights in the invention.

d. All Proposers – Intellectual Property Representations

Provide a good faith representation that you either own or possess appropriate licensing rights to all other intellectual property that will be utilized under your proposal for the DARPA program. Additionally, proposers shall provide a short summary for each item asserted with less than unlimited rights that describes the nature of the restriction and the intended use of the intellectual property in the conduct of the proposed research.

The proposer must provide an initial "UHPC IP Lineage" document. This document must specify all IP that is utilized in a team's UHPC System Design, initially including all UHPC background IP and how it will be utilized. This document will be updated throughout the lifespan of the program as a Phase 1 and 2 deliverables. The document will provide a clear description of IP, the ownership, licensees, and rights associated with the IP.

2. Solicitation Web Site

The solicitation web page at http://www.darpa.mil/tcto_solicitations.html will have a Frequently Asked Questions (FAQ) list.

3. Appendix A – Execution Models

An execution model is a strategic set of governing principles that guides the structure, functionality, interrelationships, and operation of all elements comprising the total system stack (hardware and software). It provides a conceptual framework for the mutual co-design of all elements, their synthesis to comprise a single computing system, and their operational synergy to achieve optimal system performance as an emergent behavior.

Tactically, an execution model delineates specific semantic and functional attributes of a system including the relationships between abstract (parallel processes, data structures, task interaction) and physical (cores, memory, networks) entities. It incorporates the definition and control of functionality and requirements for the entire compute system. This includes system trade-offs such as cost (size, power, dollars) versus performance (throughput, response time, scaling). The execution model will be driven by system functionality - at all levels, enabling technology advances, and practical constraints.

An execution model presents a single representation of an entire compute system – at all levels: all the characteristics, functionalities, operational modalities, and management policies. Common classes of systems share the same specifications and characteristics. In fact, such classes are defined by the execution model they employ, enable, and reflect. An execution model represents all layers and their respective interrelationships of the system: architecture, OS, runtime, compiler, programming models, as well as characteristics not explicitly exposed to the application program developer such as resource management policies and fine-grain scheduling. The effect of interoperability between system layers and across multiple system functionalities is, in essence, an emergent property.

Attributes of an execution model include:

- operational strategies and policies,
- parallelism and locality management methodologies,
- local (processor core) and global (system-wide) semantics,
- control of system resources including fail-safe operation and power,
- abstractions for the relationship between computer physical resources, and
- establishment of cross-system and generational commonalities.

Strategies provide the approaches to solving problems through effective system operation while exploiting new capabilities of advanced technologies and structures. Policies specify the rules for managing system operation and the invariants of functionality that must be achieved independent of the policies selected. These must be flexible to adapt to alternative technologies while enabling a balance between hardware and software resources. In addition policies, their invariant protocols and their disparate implementations will support the performance differentiation of common systems for diverse applications. Semantics provide the infrastructure to name and manipulate system entities, define action categories (such as processes, threads, functions), and describe parallelism (such as granularity, synchronization, and ordering). The specification of control of physical resources by the model will incorporate self-aware monitoring and management of system attributes, such as power, responses to system failures and attacks, and dynamic load balancing for performance optimization. A physical relationship abstraction provides a framework to represent the interactions and associations of system resources. This includes address translation, routing, protection and security, concurrency and locality, and adaptive resource allocation. An execution model will establish cross-system and generational commonality by supporting portability, stability across systems generations, and across multiple software products.

The following are examples of execution models: von Neumann; Cellular Automata; PRAM; Vector; SIMD; Static and Dynamic Dataflow; Systolic; Dynamic Dataflow; Shared-memory Multi-threaded; and Communicating Sequential Processes (CSP).

To achieve the goals of the UHPC program, management of system resources across all system levels will be required. This will necessitate new execution models to enable ExtremeScale systems to be realized. To this end, advanced execution models will serve as a tool to specify the interoperable system layers of ExtremeScale systems and thereby catalyze a paradigm shift in computing methodologies as has occurred multiple times throughout the history of high performance computing

It is expected that in order to achieve the ambitious goals of the UHPC program within the time and technology window of consideration that the new execution models to be developed will necessitate certain advances. These requirements for such a new execution model include:

- transition from static to dynamic techniques,
- expose parallelism in new ways and at unprecedented levels,
- control of locality for reduced power and latency,
- effective use of concurrency for performance,
- global name space management for ease of programming and management,
- enable lower overheads of synchronization, context switching, message handling, and other critical path control functions,
- manage and hide system latencies for lower power and higher efficiency,
- effectively manage memory hierarchy,
- provide adaptive self-aware runtime,
- enable active power control,
- distinguish between synchronous versus asynchronous operation while retaining symmetry of semantics
- fully support system morphing and re-configurability for managed power reduction and graceful degradation in the presence of faults,
- dynamic load balancing for optimal resource utilization while retaining time and power efficiency,
- support new application problem classes,

- interoperability with other models of computation,
- operation across diverse systems of the same class but different scales, implementations, and generations without programmer intervention, and
- I/O models.

Expected execution model deliverables shall include: a full state diagram; a simple application programmer's interface, which makes functionality explicit across all system levels; runtime observables; and policies and policy invariants.

Phase 1: Initial Execution Model
The deliverable document shall include a broad and clear strategy description. This shall specifically incorporate a justification of how requirements are addressed and core semantics.

Phase 2: Preliminary Execution Model
The deliverable document shall include an update of the Phase 1 deliverable that represents a complete detailed description of the execution model. An example(s) mapping of the execution model to the proposed system concept shall be provided. This document will provide the basis for Phase 3 system development, is expected to be comprehensive, but need not represent a final implementation.

Phase 3: Operational Execution Model
A complete and fully operational execution model will be delivered and demonstrated. The delivered execution model will embody the proposed system design principles of operation. The execution model will be fully documented and in a form presentable for open publication.

4. Appendix B

Streaming Sensor-Centric Computing

Streaming sensor computing is primarily characterized by high throughput numeric processing of a flow of input data from external sensors. Typically, this flow consists of discrete blocks of data of a fixed volume, arriving at a fixed cadence. Representative sensor types include multichannel radar and electro-optic, infrared, and video imagers. Typical application domains include multi-modal image formation, surface moving target indication, computer vision for robotics and autonomous vehicles, surveillance, and communications. Streaming sensor processing is frequently used in interactive systems or as a component of feedback control systems that also impose a latency requirement.

Challenging streaming applications present large volumes of data generated by the sensors, large volumes of intermediate data, relatively low arithmetic intensity (math operations per data word read or written), large volumes of computations repetitively applied to advancing frames of data, predictable data access patterns, relatively low portions of data flow that constitute feedback, and relatively small numbers of dynamic branches within the calculations. The latency requirement is often equivalent to many input block periods, making pipelined task parallelism an effective acceleration approach.

Traditional streaming sensor data is captured as fixed-point data at bit depths of 16 or less and organized into two- or three-dimensional data arrays representing a discrete frame of data. The data may pass through front-end processing performed with fixed-function or reconfigurable hardware to transform its domain, reduce its size, and convert it to the appropriate numerical format (which is usually single- or double-precision floating point) for further processing. Subsequent processing typically consists of FFTs and related transforms, n-d convolutions and correlations, n-d covariance estimations, linear solvers for structured systems, thresholding, low-order spatial averaging, and similar localized signal processing and linear algebra operations. These kernels differ widely in their spatial and temporal locality characteristics, as well as their opportunities for fine-grain parallelism. Corner turn operations to optimize access patterns are common. The final output of this processing chain is a relatively small number of results, such as potential objects of interest for a processor imaging system or language tokens for a speech processing system.

The emergence of exascale technology will enable more complex and challenging streaming sensor applications to be deployed. The availability of large numbers of floating point operations per time enables more complex operations on larger data sets. Examples of these operations are full-rank space-time adaptive processing systems and thin-plate-spline modeling for frame-to-frame registration of high resolution images. Such operations increase the arithmetic load of the algorithms and can also cause intermediate data set sizes to increase through the processing chain. These changes enable more demanding applications domains such as persistent, wide-area surveillance with knowledge extraction. Future streaming sensor applications will therefore have increased requirements in arithmetic capability, external I/O capabilities, internal memory capacity, and bandwidth. Future streaming sensor processing may add new layers of processing, such as self-aware, self-tuning capabilities to improve processor efficiency, load balancing, and resiliency.

Graph-based Computing

While extending conventional simulation applications to Exascale is very challenging, advancing informatics (as opposed to numeric) to comparable scale is far more difficult and in the long term quite possibly more important. Informatics problems differ from their numeric counterpart in their reliance on:

- symbolic data rather than numeric or character-string data and
- graph-based data structures rather than arrays (e.g., vectors, matrices)

While numeric elements of array structures are accessed by numeric indices in n-dimensional space and time, symbolic elements of graph structures are accessed by links which are either relationships that are themselves symbolic or probabilities. Typically arrays are of fixed rank and size. An important sub-class of graphs is static, but except for special cases, their elements are accessed through a process of traversal of a sequence of successive vertices and links. Graph-based computing differs from conventional computing in that operations are performed on symbolic data and access is by traversal of metadata rather than computed indices.

More challenging still are dynamic graph problems; those applications for which the data structure, i.e. the metadata, changes throughout the course of the application execution. Two major classes of problems may be recognized although this is by no means exhaustive: 1) evolving massive informational structures, and 2) rapid morphing ephemeral structures. The former are typical of large ontological structures that to first order expand in response to continued incidence of new data or through inference. The latter are typical of planning and search trees such as found in optimization like game playing (e.g., chess) and decision making (e.g., hypothesis testing). Both classes expose near fine-grain parallelism and dynamic resource allocation. However the access patterns are markedly different. In the former case, changes of conceptual context will require remapping of data (possibly from secondary storage) for locality management and load balancing. In the latter case, elements are quickly created, allocated to resources once, and as quickly eliminated. Load balancing is done on the fly as new graph components are generated but not rebalanced. More likely the partial findings are aggregated and higher levels of the search graph modified in some salient parameter (weighting) as the lower elements are eliminated to make room in finite space for other more promising parts of the search space.

Two key issues for the manipulation and modification of dynamic graphs are 1) coordination of multiplicity of simultaneous (or overlapping) but independent accesses to the same vertices or links of a graph, and 2) atomic insertion of a new vertex with links to physically distributed connecting vertices. The first requires local synchronization and coordination of the local coincident accesses. The second requires distributed compound operations to be performed to avoid deadlock and guarantee correctness. Future systems will require architecture and runtime system mechanisms for minimizing overhead and thereby increasing useful program concurrency in graph-based applications.

Chess: An Exemplar for Decision Problems

The general class of decision problems encompasses search, hypothesis testing, planning, and other combinatoric expansion informatics algorithms that are disproportionally difficult, exceed available space and time resources, and are guided by heuristics to an approximate and often non-deterministic solution. The resulting computations exhibit rapidly changing tree or directed-graph structures that expand to fill available space, are pruned to yield new resources based on least-likely paths to promote optimal solution with respect to an objective function consistent with a heuristic, and can roll-back in the presence of new information. A classic exemplar of such decision problems is the game of chess.

Non-deterministic, perfect information problems such as chess are impossible to compute exhaustively and rely on heuristic based approximate results. Due to the rapidly expanding trees, the complete game tree generated is intractable given finite resources and finite time. Heuristic approaches help reduce the search space considerably by eliminating paths that do not contribute towards the final outcome. However even such approaches are sensitive to ordering and are very sensitive to the quality of the heuristic evaluation functions. The supporting computational ecosystem for such class of problems needs to be able to optimally represent global data structures, and allow for effective mechanisms that facilitate dynamic expansion and contraction of trees. As the computed results get percolated from the terminal leaf nodes towards the root node, efficient global communication mechanisms would be needed to allow for propagation of results across a global data structure. Finally the execution models of the computational ecosystem need to facilitate prioritized critical-path execution by suspending non-critical execution paths through supporting scheduling and resource management mechanisms and policies.

The Game of Chess exhibits the following properties: perfect information (chess-board represents comprehensively the state of the game at all times), slow convergence with subgoals of material superiority (number of opponent chess pieces) and sudden-death (as a result of endgame scenarios). Computer chess programming usually involves representation of sequences of possible moves in the form of a tree, which comprises each player's choice of different moves and the corresponding responses by the opponent. The game tree is traversed, and an evaluation function is applied at each node, to determine the best moves based on evaluation of consequences of each potential move. In chess the number of possible moves per position can range anywhere between 30 – 218, consequently the game tree evaluations explode exponentially with every possible iteration (until the players reach an endgame scenario). Taking the lower bound estimate of 30 legal moves per side with an empirical estimate of 40 moves per side per game, the game tree complexity of a typical chess game is 10^{120} (Shannon Number). Consequently a computer chess playing problem is a PSPACE problem (problem space can be represented in memory (large amount) however evaluation of the tree would be of nondeterministic polynomial time complexity. In practical computer chess programs, heuristics such as min-max and pruning methods like alpha-beta are used to reduce the size of the game tree. The resultant chess programs search to a specified depth in the game tree and rely on heuristic evaluation functions such as material balance (number & value of pieces held by each side) and strategic balance (composite measures such as mobility, square control, etc) to control the state of the game in each iteration.

Min Max is a classic depth first search problem. First step in the Min Max approach is to generate the entire game tree (up to a specified depth), the same search tree is utilized for both players such that the even layers are used for Max player moves and the odd layers for the Min player moves. The terminal leaf nodes of the game tree are evaluated to represent Material and/or Strategic balance offered by each of the moves. An example evaluation function can be of the for $F(p) = 400(K\text{-}K') + 20(Q\text{-}Q') + 10(R\text{-}R') + 5(B\text{-}B' + N\text{-}N')+2(P\text{-}P') + \ldots$ The values generated for each of the nodes are propagated up the search tree from the terminal leaf nodes. The nodes that belong to the Max player are populated with the maximum value of their children and Min player nodes are populated with the minimum value of its children. The Max player chooses the move with the highest value and the Min player chooses the move with lowest value. The time complexity for a min max with branching factor of b and depth d is $O(b^d)$. Even for the relatively low branching factor of 36, a 10 ply search would require 36^{10} nodes to search. The space complexity is of the order $O(bd)$. Due to the large search space and subsequent time complexity, optimizations are needed to make the problem more tractable. The alpha-beta pruning heuristic reduces the effective branching factor allowing trees of twice the depth, than that of Min Max, to be searched in the same time.

Alpha-beta pruning reduces the number of nodes that are evaluated by discarding moves that are worse than previously evaluated nodes, thereby eliminating the values that do not influence the final result. Alpha initialized to negative infinity and beta is initialized to positive infinity. The steps involved are the same as Min-Max, the main difference being the values of Alpha and Beta are modified during runtime based on the evaluation of each node. The pruning algorithm maintains the minimum score that the maximizing player is assured of and the maximum score that the minimizing player is assured of by storing them in alpha and beta respectively. As the execution progresses the gap between alpha and beta becomes smaller. When beta becomes larger than alpha for a particular node, it implies that remaining nodes of the sub-tree do not need to be processed as they do not affect the outcome of the game. The time complexity for an alpha-beta with branching factor of b and depth d is $O(b^{d/2})$. Even for the relatively low branching factor of 36, a 10 ply search would require $36^{10/2} = 6^{10}$ nodes to search.